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SPACE SHUTTLE AFRSI FULL-SCALE APPLICATION DESIGN ISSUES TEST OS311 IN THE AMES RESEARCH CENTER (ARC) 11x11-FT WIND TUNNEL USING MODEL 127-0 INSTALLED IN THE 96-0 TEST FIXTURE

by

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National Aeronautics and Space Administration
Houston, Texas

WIND TUNNEL TEST SPECIFICS:

	ARC	ARC	ARC	ARC
Test Number:	562-2-11	562-3-11	562-4-11	562-5-11
NASA Series Number:	OS-311-1	OS-311-2	OS-311-3	OS-311-4
Model No. of Test Fixture:	96-0	96-0	96-0	96-0
Test Start Date:	1-28-83	3-3-83	4-12-83	6-12-83
Test Completion Date:	1-28-83	3-7-83	4-13-83	6-12-83
Occupancy Hours:	4	20	24	20

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SPACE SHUTTLE AFRSI FULL-SCALE APPLICATION DESIGN ISSUES TEST OS-311 IN THE AMES RESEARCH CENTER (ARC) 11x11-FT WIND TUNNEL USING MODEL 127-O INSTALLED IN THE 96-O TEST FIXTURE

by

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ABSTRACT

An experimental investigation (OS-311) was conducted in four parts in the NASA/ Ames Research Center 11x11-foot Transonic Wind Tunnel. The objective was to investigate AFRSI installation designs and support the determination of MR/DR criteria. The first test (OS-311-1) was conducted on January 28, 1983, the second test (OS-311-2) on March 3 through 7, 1983, the third test (OS-311-3) on April 12 and 13, 1983, and the final test (OS-311-4) on June 12, 1983. AFRSI material, configured on small test panels for application design, repairs, contamination, and MR/DR criteria evaluation were subjected to ascent aerodynamic shock loading environments which resulted in qualitative evaluation of the various configurations tested. The transonic compression shock fixture, 96-O, was used to generate the aerodynamic loading environment. Twenty-seven runs were completed during 68 hours of occupancy. Of the 27 test articles, only nine were exposed to thermal conditions prior to the wind tunnel test, and one was exposed to the actual STS-6 flight. During each of the four phases of Test OS-311, local fixture static pressures on each side of the test article were measured and recorded. Fluctuating pressure data was also obtained during these tests.

All test objectives were met. This report contains information on the conduct of Test OS-311, description of the test fixture, and the specimen, the test facility, instrumentation, and a sample of the pressure data collected during the test. Post-test pictures of the test fixture and the AFRSI test articles are also included.

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INTRODUCTION

Advanced Flexible Reusable Surface Insulation (AFRSI) has replaced white TPS tile on parts of OV-099 and OV-103. The purpose of the test was to obtain data to assist in the selection of installation designs and the determination of MR/DR criteria.

The test was conducted using the 96-0 test fixture to generate the required flow field over the AFRSI test articles. The leading edge flap of the test fixture was set at 18 degrees during the entire test and the AFRSI specimens were exposed to the ascent airloads environment until failure, or for a simulation of 100 missions (42 minutes). The aerodynamic shock environment used in the Ames Research Center 11x11-foot Transonic Wind Tunnel was an expansion/ recompression shock generated by the leading edge flap on the 96-0 test fixture at free stream Mach numbers from 0.8 to 0.88. The tunnel free stream stagnation pressure was set to simulate the ascent flow field and aerodynamic loading over the orbiter canopy.

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NOMENCLATURE

SYMBOL	MNEMONIC	DEFINITION
C_p	CP	Pressure coefficient
dB	DB	Sound pressure level, dB (Decibel)
M	Mach	Freestream Mach number
P_∞	P	Freestream static pressure, psia
P_ℓ	PL	Local static pressure, psia
P_{RMS}	PRMS	Local fluctuating pressure, PSI RMS
P_t	PT	Freestream total pressure, psia
q	Q	Freestream dynamic pressure, psf
R_e	RE	Freestream Reynolds number, per ft
T_s	TS	Freestream static temperature, ^oF
T_t	TT	Freestream total temperature, ^oF
V_∞	VEL	Freestream velocity, ft/sec
X	X	Longitudinal distance positive, inches aft of test article leading edge
Y	Y	Lateral distance positive, inches right of fixture centerline
δ_F	FLAP	Test fixture flap setting, degrees
ρ	RHO	Freestream density, slugs/ft^3

Other symbology includes:

AFRSI	Advanced Flexible Reusable Surface Insulation
OML	Outer Mold Line
IML	Inner Mold Line
TOC	Time on Condition
DR	Discrepancy Report
MR	Material Review
RMS	Root-Mean Square

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REMARKS

During the initial phase of Test OS-311-1, of the original nine test articles scheduled to be tested, only two were completed. Neither of the two panels were damaged after 42 minutes on-condition. The remaining seven test articles were rescheduled during Test OS-311-2.

On Test OS-311-2, of the 15 test articles, six were damaged prior to obtaining 42 minutes on-condition. (See Test Summary, Table VI.)

CONFIGURATION INVESTIGATED

Model Description

The 96-0 test fixture was used for Test OS-311. The test fixture, shown in Figures 2.a and 2.b, consists of a flap mounted at the leading edge of a specimen holding frame, two side plates, and a sealed pressure box enclosing the space beneath the holding frame. The function of the leading edge flap is to cause an expansion shock ahead of the test article, followed by a recompression shock region with attendant positive pressure gradients and high turbulence levels over the test article.

The mechanism employed to produce the desired expansion/recompression shocks was a full-span, 15-inch chord flap located at the forward end of the test panel. For this test, a turnbuckle replaced the hydraulic cylinder and was adjusted to lock the flap at 18 degrees. The fixture had end plates to make the flow field in the test area two-dimensional. The end plates (98 x 56 inches) extended from a height of three feet above the top of the test panel all the way to the floor, and were supported from underneath. The beveled leading edges were located 26 inches forward of the test specimen's leading edge.

A sealed pressure box enclosed the area under the panel. The box was vented to the tunnel plenum chamber. Also, shims and spacers were available for the test article to bring its leading edge flush with the surface of the fixture. These were intended to compensate for the 6.54-inch depth of the supporting frame inside the test fixture.

Test Article

Model 127-O designates 27 test articles, Table V, which were made up of a support plate, the AFRSI bonded to the support plate, and a frame which protected and held the AFRSI edges. When installed, the frame of the test specimen was flush with the adjacent surface of the fixture to the extent possible, particularly at the leading edge. Figures 2.c and 2.d illustrate the model configuration.

Test Specimens

The AFRSI blankets consisted of silica fiber felt (Q-felt) insulation material with a silica cloth covering and a glass cloth back lining, all quilted together with quartz thread in a one-inch square grid pattern. The quilting was done with a modified lock stitch. The outer covering (OML) was made of a heavy cover fabric which is approximately 0.027-inch thick (19.5 oz/yd^2 silica fabric). The batting used for these specimens was silica batting (six lb/cu ft). The inner cover (IML) was made of a 0.010-inch thick light cover (six oz/yd^2 S-glass fabric). The OML threads used were Q24 silica thread while the IML threads were made of E-glass threads. A sketch of a test specimen assembly is shown in Figures 2.c and 2.d.

INSTRUMENTATION

Data recorded during Test OS-311 were measured by Scanivalves attached to static pressure orifices and dynamic pressure transducers (Kulites).

Static Pressure

The test fixture was instrumented with 28 static pressure taps, fourteen on each side of the test specimen area. These 28 static pressure ports were connected to six scanivalve (one six-pack) as shown in Table IV. The instrumentation location for the 96-0 test fixture is shown in Figure 1 and presented in Table III. Data from these taps were recorded during all runs. Rockwell supplied all necessary tubing, transducers, scanivalves, and associated cabling.

Fluctuating Pressure

The 96-0 test fixture was instrumented with fourteen Kulite transducers to measure peripheral fluctuating pressures. Their locations are shown in Figure 1 and listed in Table III. The reference tube of all Kulites were connected to a common manifold which was vented to the tunnel static pressure. All power supplies and signal conditioning equipment associated with the Kulite transducers were supplied by ARC. Tunnel static pressure was recorded on tape with the Kulite data.

TEST FACILITY DESCRIPTION

The NASA Ames Research Center 11-ft Transonic Wind Tunnel is the transonic leg of the Ames Unitary Facility. It is a closed circuit, single return, continuous flow, variable-density tunnel. The 11x11x22-ft test section is slotted to permit transonic testing. The nozzle has adjustable sidewalls. The tunnel air is driven by a three-stage axial flow compressor powered by four wound-rotor induction motors. The speed of the motors is varied as necessary to provide the desired Mach number. The motors have a combined output of 180,000 horsepower for continuous operation or 216,000 horsepower for one hour. Tunnel temperature is controlled by aftercoolers and a cooling tower. Four 30,000 cubic-foot storage tanks provide dry air for tunnel pressurization.

The tunnel can be operated at nominal Mach numbers of 0.5 to 1.4 Reynolds number per foot x 10^{-6} of 1.7 to 9.4, dynamic pressure (PSF) of 150 to 2,000 and a total temperature (^{o}F) of 540 to 610, respectively.

This tunnel is used for force and moment, pressure, internal air-flow inlet, and dynamic stability tests.

TEST PROCEDURES

During each of the four phases of Test OS-311, the procedure was to test each AFRSI test article to failure, or for 42 minutes (equivalent of 100 ascent missions with a scatter factor of 4). After the test article was inspected and the tunnel door was closed, the tunnel was pumped down to 28 inches of Mercury for a Scanivalve check. The tunnel was then pumped up to 33 inches of Mercury and the tunnel drive was started. The television and Kulite recorders were turned on and static pressures were recorded continually as the tunnel was being brought to M = 0.80. In all instances, the flap was kept at a constant angle of 18 degrees.

As q reached 400 psf, the environment exposure time was started. After the Mach reached 0.8, the tunnel cycled Mach from 0.8 to 0.88, and back to 0.8 as time would allow. When the test article lasted for 100 missions, the tunnel was brought off-line so that the time that q was above 400 psf would be equal to 42 minutes. If the test article failed, a fast stop would be initiated as soon as the failure occurred. In all cases, the exposure time stopped when q became less than 400 psf. The Kulite and television recorders were then turned off and the test article was inspected after the tunnel door was opened.

The amount of time that each panel was exposed to a dynamic pressure greater than or equal to 400 psf during this test was approximately 42 minutes, or an equivalent of 100 missions. During Phase 2, seven of the specimens were exposed to less than 42 minutes on condition as shown in the Test Summary, Table VI, and in the acutal Run Schedule, Table II. A summary of test conditions is shown in Table I, and a comparison of the ascent airloads environment to which the test articles were exposed at is shown in Figure 3.

DATA REDUCTION

Standard tunnel equations were used for computing all tunnel conditions. All local static pressure data were reduced to standard pressure coefficient form using the following equation:

$$C_p = \frac{(P_L - P) \times 144}{q}$$

Typical pressure coefficient data is shown in Figure 3.

Fluctuating pressure data were recorded on magnetic tape and reduced during and after the test.

Local fluctuating pressure data were reduced to dB form as follows:

$$dB = 10 \, Log_{10} \frac{P_{RMS} \times 10^9}{2.94}^2$$

REFERENCE

1. R. B. Kingsland, STS83-0084, "Pre-Test Information for the AFRSI Application Design Issues Test OS-311 in the Ames Research Center (ARC) 11x11-ft Wind Tunnel Using Model 127-O Installed in the 96-O Test Fixture" (January 1983)

TABLE I

TEST CONDITIONS - OS-311

P_T=CONSTANT=33 IN.HG /16.14 PSI/2326 PSF

MACH	Ps			q		
	IN.HG	PSI	PSF	IN.HG.	PSI	PSF
.55	26.89	13.15	1894	5.68	2.78	400
.80	21.55	10.59	1525	9.70	4.74	683
.82	21.22	10.38	1495	9.99	4.88	704
.84	20.79	10.17	1464	10.27	5.02	723
.86	20.36	9.96	1434	10.54	5.16	743
.88	19.35	9.75	1404	10.81	5.29	761

TABLE II.a

Post Test Run Schedule (ARC 11 x 11-foot) OS-311-1

TEST: OS-311-1 | DATA SET/RUN NUMBER COLLATION SUMMARY | DATE: 1-28-83

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_f	P_T	in.Hg		TOC (MIN)	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) .80		.82		.84		.86		.88	
3	TA 311A-2			18°	33			41	✓		✓		✓		✓		✓	
4	TA 311A-3			18°	33			43	✓		✓		✓		✓		✓	

Note: Mach number was cycled back and forth from 0.80 to 0.88 to 0.80 for approximately 42 minutes. Data was taken at each Mach number. (See Test Chronology)

TEST RUN NUMBERS

TYPE OF DATA α OR β SCHEDULES

TOC - Time On Condition

✓ - Data Point

COEFFICIENT SCHEDULES

IDVAR (1) IDVAR (2) NDV

TABLE II.b

POST TEST RUN SCHEDULE (ARC 11X11-FOOT) OS-311-2

TEST :

DATA SET/RUN NUMBER COLLATION SUMMARY

DATE : MARCH 4, 7, 1983

RUN #	CONFIGURATION I.D	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_c	PARAMETERS/VALUES β_T			TOC (min)	MACH NUMBERS (OR ALTERNATE INDEPENDENT VARIABLE) .80		.82		.84		.86		.88		TEST RUN NUMBERS
6	TA 311B-5			18°	33			42	✓		✓		✓		✓		✓		
7	311B-6			18°	33			27	✓		✓		✓		✓		✓		
8	311B-7			18°	33			42	✓		✓		✓		✓		✓		
10	311B-15			18°	33			12	✓		✓		✓		✓		✓		
11	311B-14			18°	33			42	✓		✓		✓		✓		✓		
12	311B-4			18°	33			11	✓		✓		✓		✓		✓		
13	3NB-11			18°	33			8	✓										
14	311B-2			18°	33			42	✓		✓		✓		✓		✓		
15	311B-3			18°	33			42	✓		✓		✓		✓		✓		
16	311B-1			18°	33			42	✓		✓		✓		✓		✓		
17	311B-8			18°	33			6	✓		✓		✓						
18	311B-9			18°	33			42	✓		✓		✓		✓		✓		
19	311B-12			18°	33			42	✓		✓		✓		✓		✓		
20&21	311B-13			18°	33			42	✓		✓		✓		✓		✓		
22	3NB-10			18°	33			8	✓		✓		✓		✓		✓		

TYPE OF DATA α OR β SCHEDULES

TOC - TIME ON CONDITION COEFFICIENT SCHEDULES

✓ - DATA POINT

IDVAR (1) IDVAR (2) NDV

TABLE II.c

Post Test Run Schedule (ARC 11 x 11-foot) OS-311-3

TEST: OS-311-3 | DATA SET/RUN NUMBER COLLATION SUMMARY | DATE: April 13, 1983

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES δ_F	PARAMETERS/VALUES P_t	PARAMETERS/VALUES in. H_g	TOC (MIN)	MACH NUMBERS FOR ALTERNATE INDEPENDENT VARIABLE .80	.82	.84	.86	.88	TEST RUN NUMBERS
6	T/A 311C - 1			18°	33		42	✓	✓	✓	✓	✓	
5	T/A 311C - 2			18°	33		42	✓	✓	✓	✓	✓	
8	T/A 311C - 3			18°	33		42	✓	✓	✓	✓	✓	
9	T/A 311C - 4			18°	33		42	✓	✓	✓	✓	✓	
10	T/A 311C - 5			18°	33		42	✓	✓	✓	✓	✓	

Note: Mach number was cycled back and forth from 0.80 to 0.88 to 0.80 for 42 minutes. Data were taken at each Mach number. (See test Chronology)

TYPE OF DATA α OR β SCHEDULES

TOC = Time On Condition
✓ = Data Point

COEFFICIENT SCHEDULES

IUVAN (1) IUVAN (2) NOV

NASA-MSFC-MAF

TABLE II.d

POST TEST RUN SCHEDULE (ARC 11 X 11-FOOT)

TEST: OS 311-4 | DATA SET/RUN NUMBER COLLATION SUMMARY | DATE: JUNE 12, 1983

DATA SET IDENTIFIER	CONFIGURATION	SCHD. α	SCHD. β	PARAMETERS/VALUES	EXPOSURE TIME MIN.	EXPOSURE TIME SEC.	MACH NUMBERS .80	.82	.84	.86	.88
4	T/A 311-4-1			18° / 33	42		✓	✓	✓	✓	✓
5	T/A 311-4-3			18° / 33	42	20	✓	✓	✓	✓	✓
6	T/A 311-4-4			18° / 33	42	35	✓	✓	✓	✓	✓
7	T/A 311-4-5			18° / 33	40	49	✓	✓	✓	✓	✓
8	T/A 311-4-6			18° / 33	42	52	✓	✓	✓	✓	✓

TEST RUN NUMBERS

NOTE: MACH NO. WAS CYCLED BACK AND FORTH FROM 0.80 TO 0.88 TO 0.80 FOR ≈ 42 MIN. DATA WAS TAKEN AT EACH MACH NO. (SEE TEST CHRONOLOGY).

1 7 13 19 25 31 37 43 49 55 61 67 75 76

COEFFICENTS IDVAR (1) IDVAR (2) NDV

α OR β SCHEDULES

TABLE III

INSTRUMENTATION LOCATION, FIXTURE 96-O

X \ Y	STATIC TAPS						Kulites at Y=16
		-16				16	
0		201				101	
1		202				102	K1
2		203				103	K2
4		204				104	K3
6		205				105	K4
8		206				106	K5
10		207				107	K6
12		208				108	K7
14		209				109	K8
16		210				110	K9
18		211				111	K10
20		212				112	K11
24		213				113	K12
30							K13
36		214				114	K14

TABLE IV

SCANIVALVE ORIFICE ASSIGNMENT

PORT	MEASUREMENT NUMBER / DRIVE VALUE					
	1	2	3	4	5	6
0	REF	→	→	→	→	→
1	CAL	→	→	→	→	→
2	101	102	103	104	105	106
3	107	108	109	110	111	112
4	113	114	201	202	203	204
5	205	206	207	208	209	210
6	211	212	213	214	—	—

96-O TEST FIXTURE

11-FT TUNNEL (OS-311)

TABLE V.a

TEST ARTICLE DESCRIPTION OS-311-1

I.D.	NAME	DETAILED DESCRIPTION
A-2	MIN BOND PRESS	AFRSI APPLIED WITH MIN BOND PRESS ~1 PSI
A-3	MIN BOND PRESS + PLUG	SAME AS A-2 PLUS REPAIR PLUG WITH 1/4 PSI BOND PRESS

TABLE V.b

TEST ARTICLE DESCRIPTION OS-311-2

I.D.	NAME	DETAILED DESCRIPTION
B-1	F/B-Pad Bond	6" Strip: No Bond Filler Bar-to-Blanket
B-2	T/C Stitchlines	IML Stitchlines only were transfer-coated.
B-3	56% Bond	Only ≈56% of IML surface bonded to plate.
B-4	Grease, RTV + 1500°F	Exposed to one cycle at 1500°F in plasma Arc - grease on fabric and RTV spots.
B-5	Narrow Strip	1.25" wide blanket evaluated.
B-6	Thick Pad	1.94" thick pad fabricated by RI's AMT.
B-7	Gypsum	Several weeks outdoor exposure at WSTF.
B-8	Salt Spray (HS + 1800°F)	5 cycles at 1800°F in plasma Arc, ≈2.4g/M^2 salt (year exposure).
B-9	Salt Spray (NS + 1800°F)	5 cycles at 1800°F in plasma Arc: No salt
B-10	Salt spray (HS + 1500°F)	5 Cycles at 1500°F in plasma Arc, ≈2.4g/M^2 salt (year exposure)
B-11	Salt spray (NS + 1500°F)	5 cycles at 1500°F in plasma Arc: No salt
B-12	1/8" Holes	1/8" Puncture holes - damage evaluation
B-13	Thick Pad	Duplicate of 311B-6
B-14	RTV + 1500°F	Exposed to one cycle at 1500°F in plasma Arc - RTV bleedthrough & spill
B-15	1500°F	Exposed to one cycle at 1500°F in plasma Arc

TABLE V.c

TEST ARTICLE DESCRIPTION OS-311-3

I.D.	T/A NAME	DETAILED DESCRIPTION
C-1	CUT REPAIR	1/2" CUT REPAIR: LOOP STITCHING
C-2	DAMAGE ALLOWABLE	1/4" OML CUTS
C-3	GAP FILLERS	RECESSED PILLOW-TYPE GAP FILLERS
C-4	GAP FILLERS	RECESSED SOLID CORD (0.90", 0.160") GAP FILLERS
C-5	SIDEWALL REPAIR	FABRIC (0.011") SIDEWALL REPAIR

TABLE V.d

TEST ARTICLE DESCRIPTION OS-311-4

I.D.	NAME	DETAILED DESCRIPTION
4-1	Hi Fiber 1" Stitching	Control Panel No Thermal Exposure
4-3	Hi Fiber 1" Stitching	Bird Dropping
4-4	Hi Fiber 1" Stitching	Salt spray and plasma ARC thermal exposure to 1500°F
4-5	Hi Fiber 1" Stitching	Salt spray and plasma ARC thermal exposure to 1800°F
4-6	STS-6 Flight OMS Pod Blanket	STS-6 flight blanket repaired seams

TABLE VI

OS-311 TEST SUMMARY

Test Article	Δ Time q=400 psf to M=0.80	Number of Cycles M=.8→.88→.8	Time q=400 psf to Tunnel Start Off Line (Min.)	Exposed Time q=400 Going Up to q=400 Going Down (Min.)	* Post-Test Condition
A-2	3	4.5	40	41	(1)
A-3	3	5	41	43	(1)
B-1	2	5	40	42	No Change
B-2	4	3.5	40	43	No Change
B-3	2	4.5	39	41	No Change
B-4	2	1	11	11	(2)
B-5	2	7.5	41	43	No Change
B-6	5	2	26	26	(3)
B-7	2	5	40	41	No Change
B-8	3	0	6	6	(4)
B-9	2	4	40	42	No Change
B-10	2	1	8	8	(5)
B-11	2	0	8	8	(6)
B-12	2	5	40	42	No Change
B-13 (Run 20)	3	0	6	6	(7)
B-13 (Run 21)	2	5	34	36	No Change
B-13 (Total)	5	5	40	42	No Change
C-1	2	3	40	42	No Change
C-2	3	7	40	42	No Change
C-3	2	4	41	42	No Change
C-4	2	3.5	39	42	No Change
C-5	2	9.5	40	42	(9)
4-1	8	2.75	39	42	No Change
4-3	7	4	41	42	(10)
4-4	5	4.5	40	43	(11)
4-5	3	5	38	41	(11)
4-6	8	5.3	41	43	No Change

*See notations on following page.

TABLE VI (Concluded)

OS-311 TEST SUMMARY

(1)	A-2/A-3	Slight lifting or separation at joints.
(2)	B-2	OML cover lost aft left hand side.
(3)	B-6	OML cover out from under trailing edge frame.
(4)	B-8	OML cover and matting lost forward right side.
(5)	B-10	OML cover and matting lost aft half.
(6)	B-11	OML cover and matting lost aft left hand side.
(7)	B-13	OML cover pulled out from under trailing frame during Run 20, stopped, repaired, and ran again as Run 21.
(8)	B-15	Lost all OML cover and matting.
(9)	C-5	Torn repair.
(10)	4-3	Two rips not related to bird's deposit locations.
(11)	4-4/4-5	Broken Threads

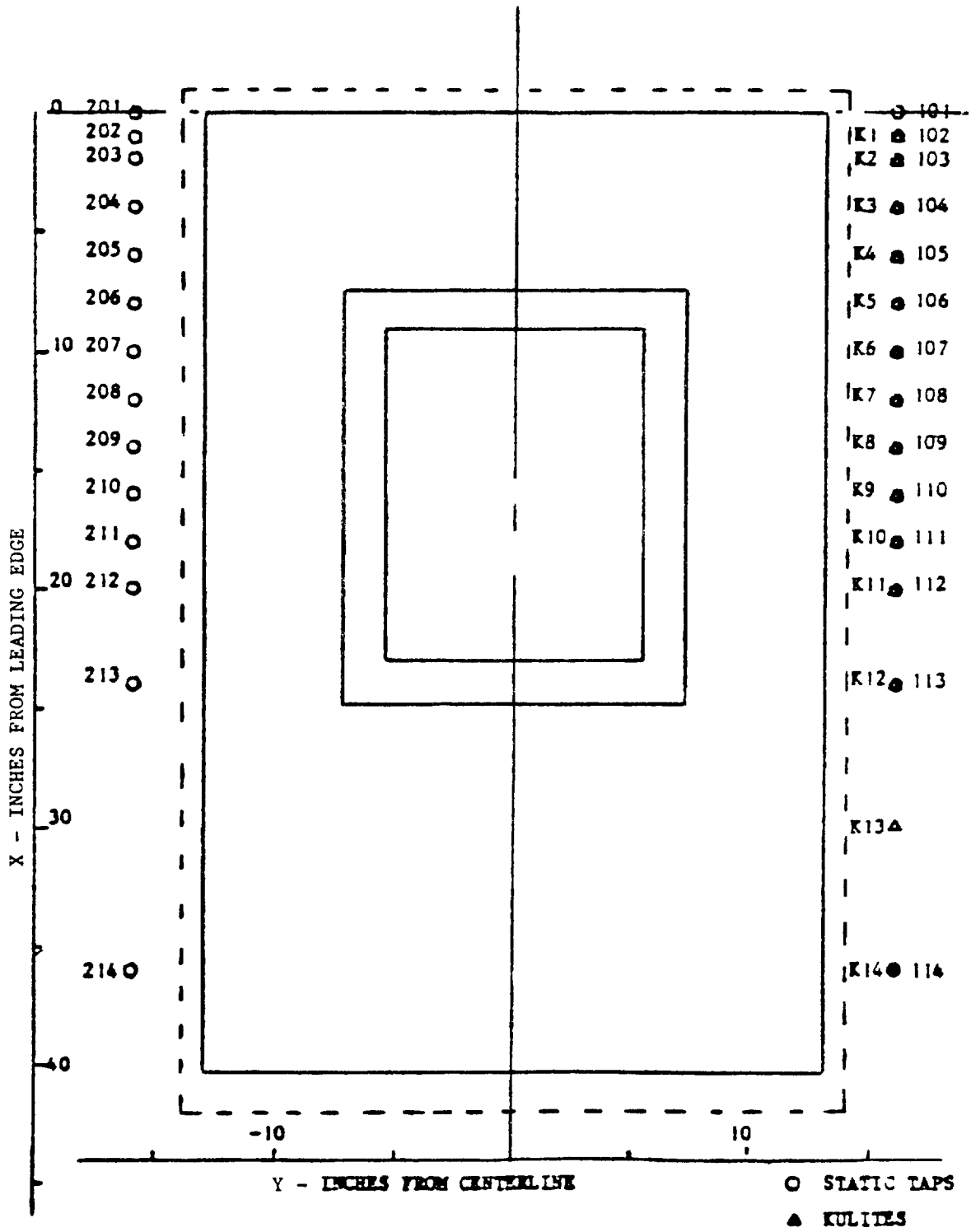


FIGURE 1 INSTRUMENTATION LOCATION & AXES
96-Ø TEST FIXTURE

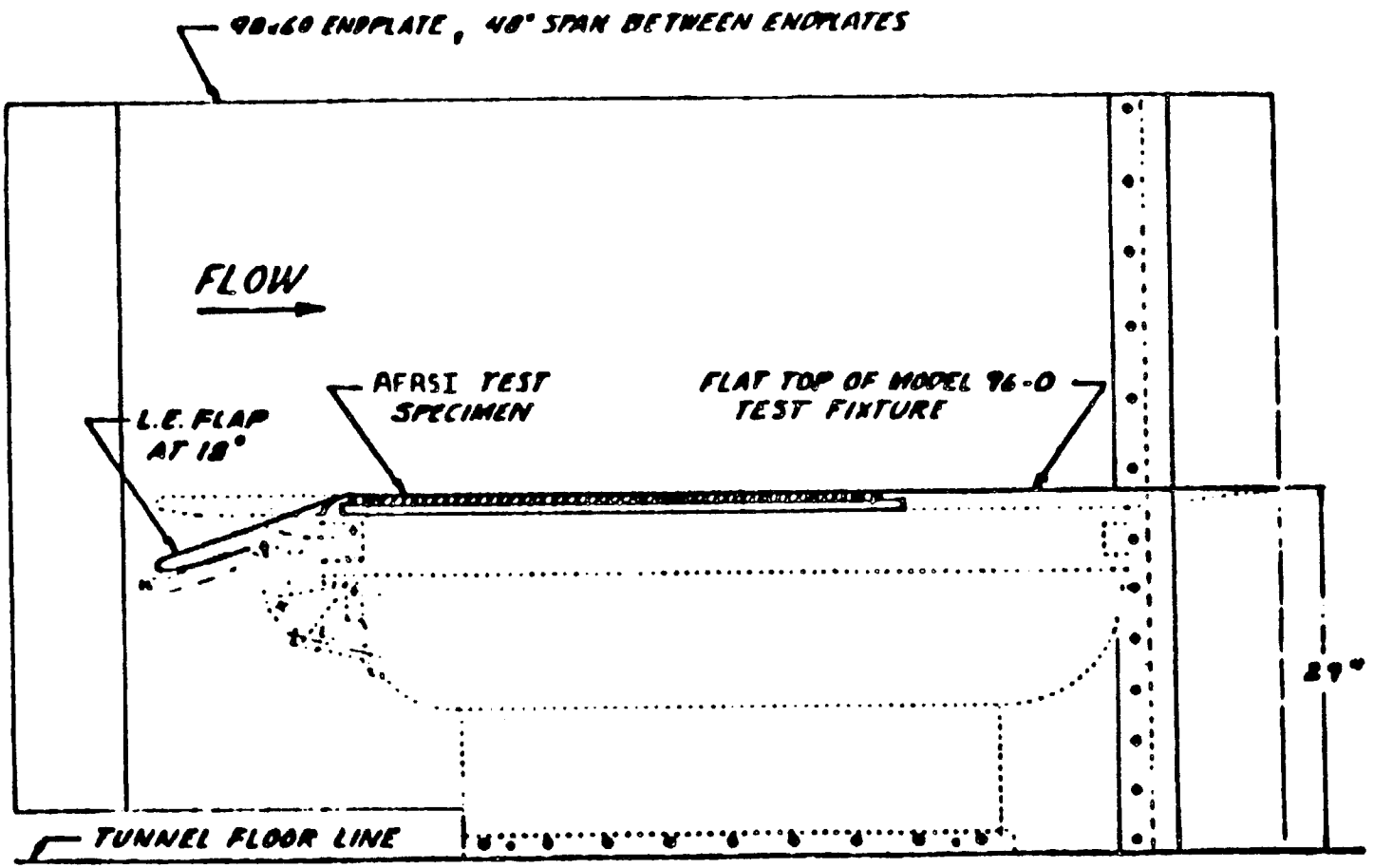


FIGURE 2.a MODEL 96-Ø TEST FIXTURE GENERAL ARRANGEMENT OS311

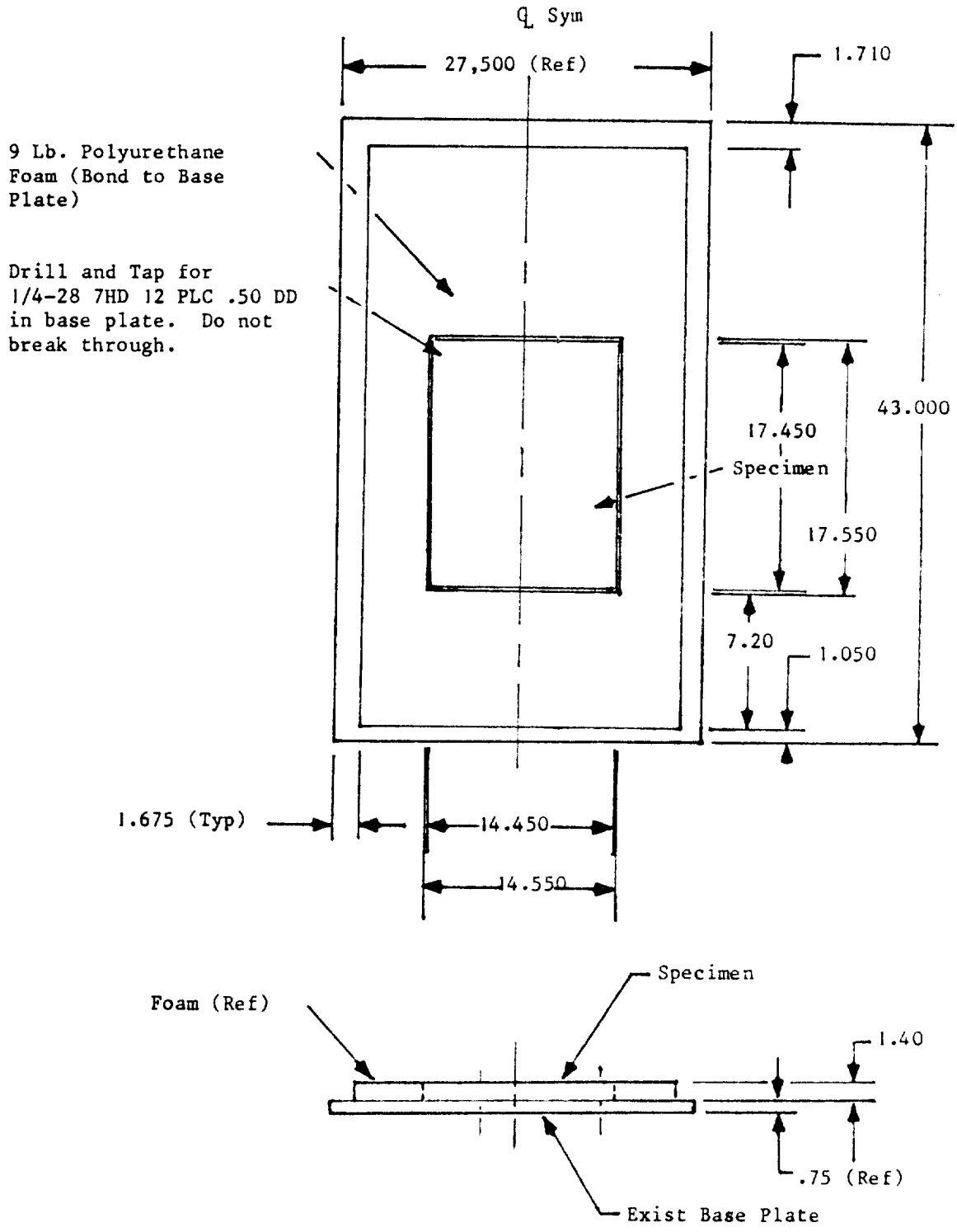
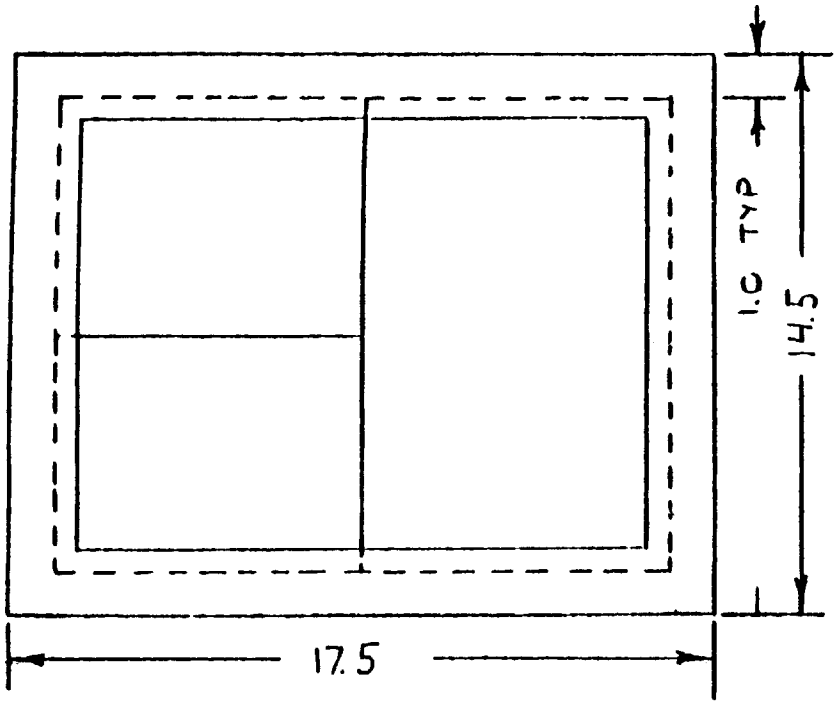
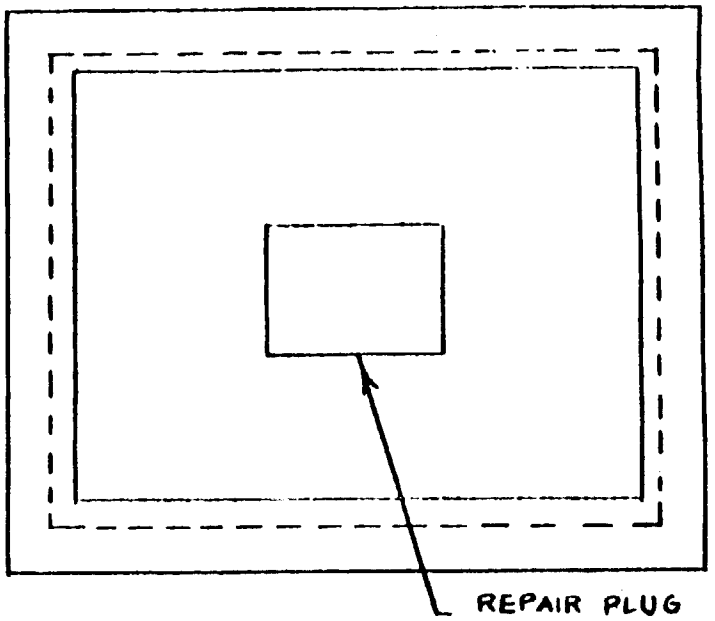
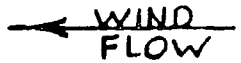
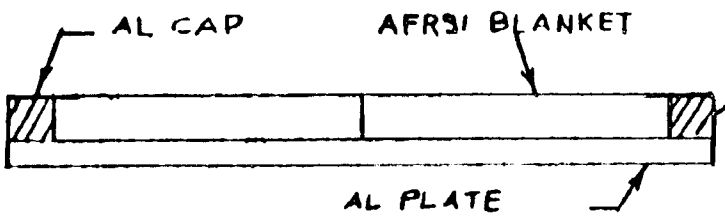


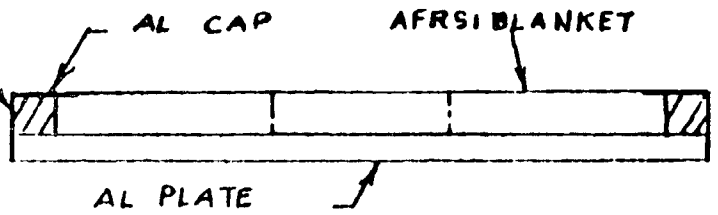
FIGURE 2.b MODEL 96-O FIXTURE HOLDING PANEL











NOTE: CURRENT MIN. BONDING PRESSURE (MPP 606M317M01) IS 1 PSI.

FIGURE 2.c TEST ARTICLE A-2 LAYOUT

FIGURE 2.d TEST ARTICLE A-3 LAYOUT

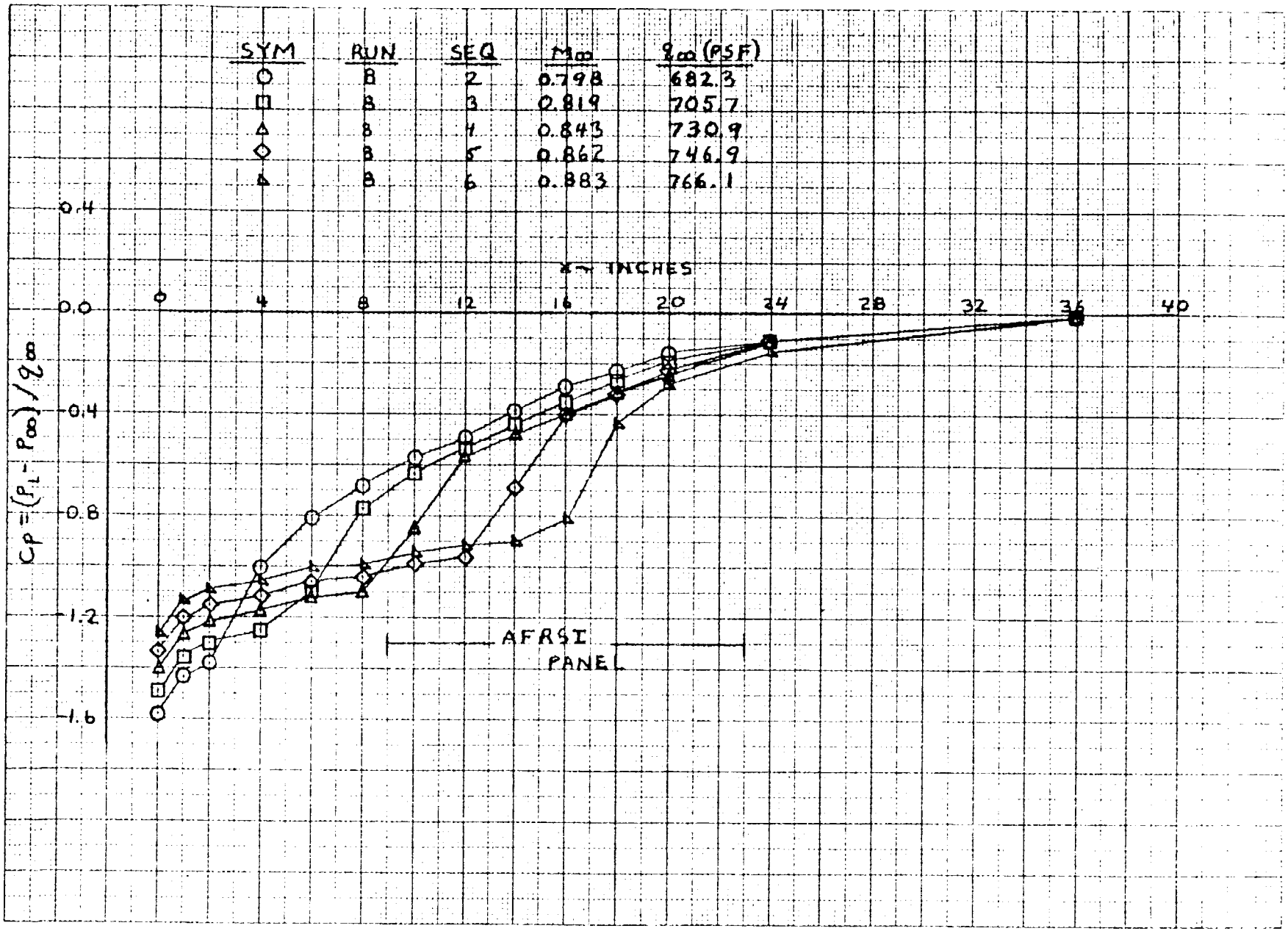
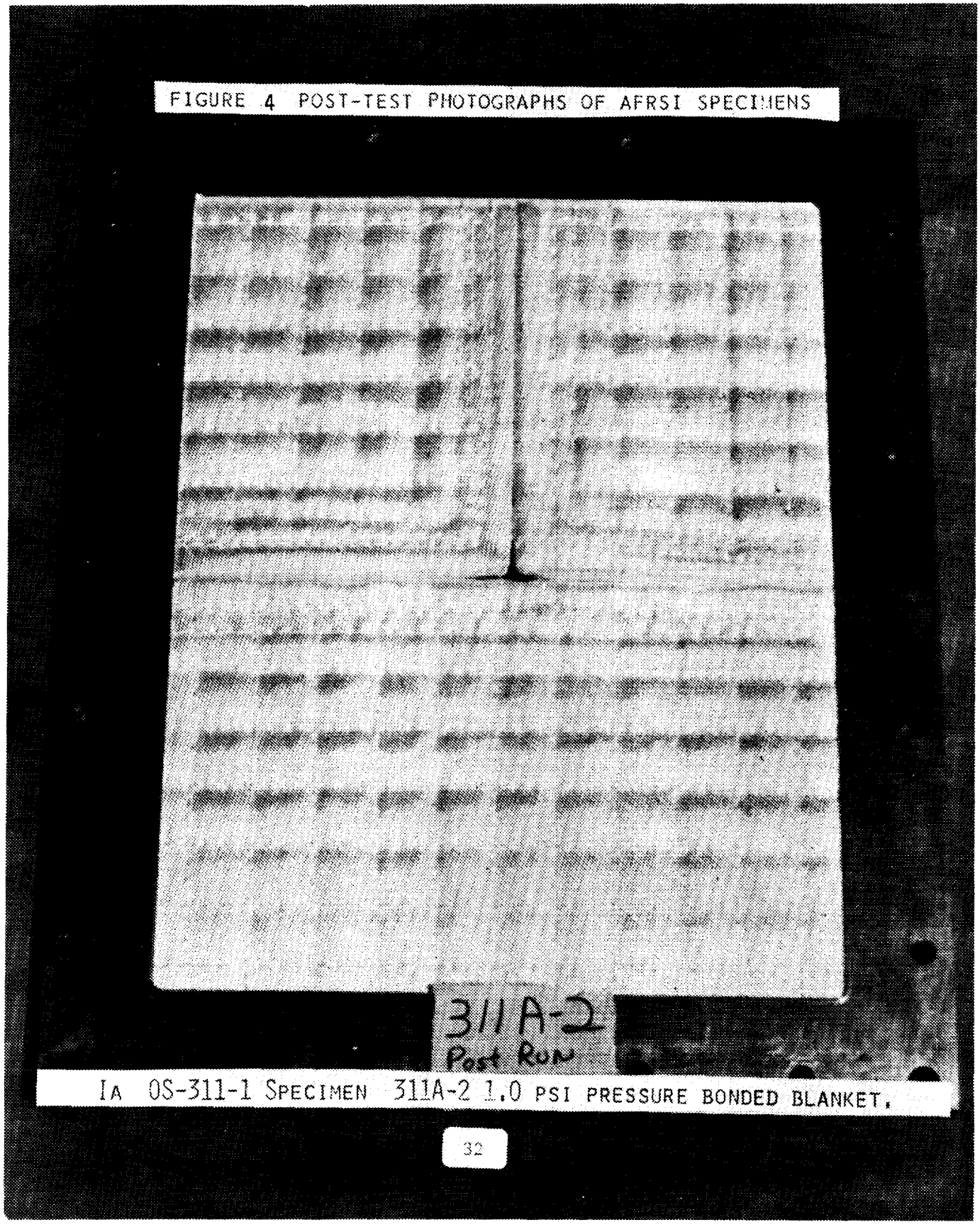


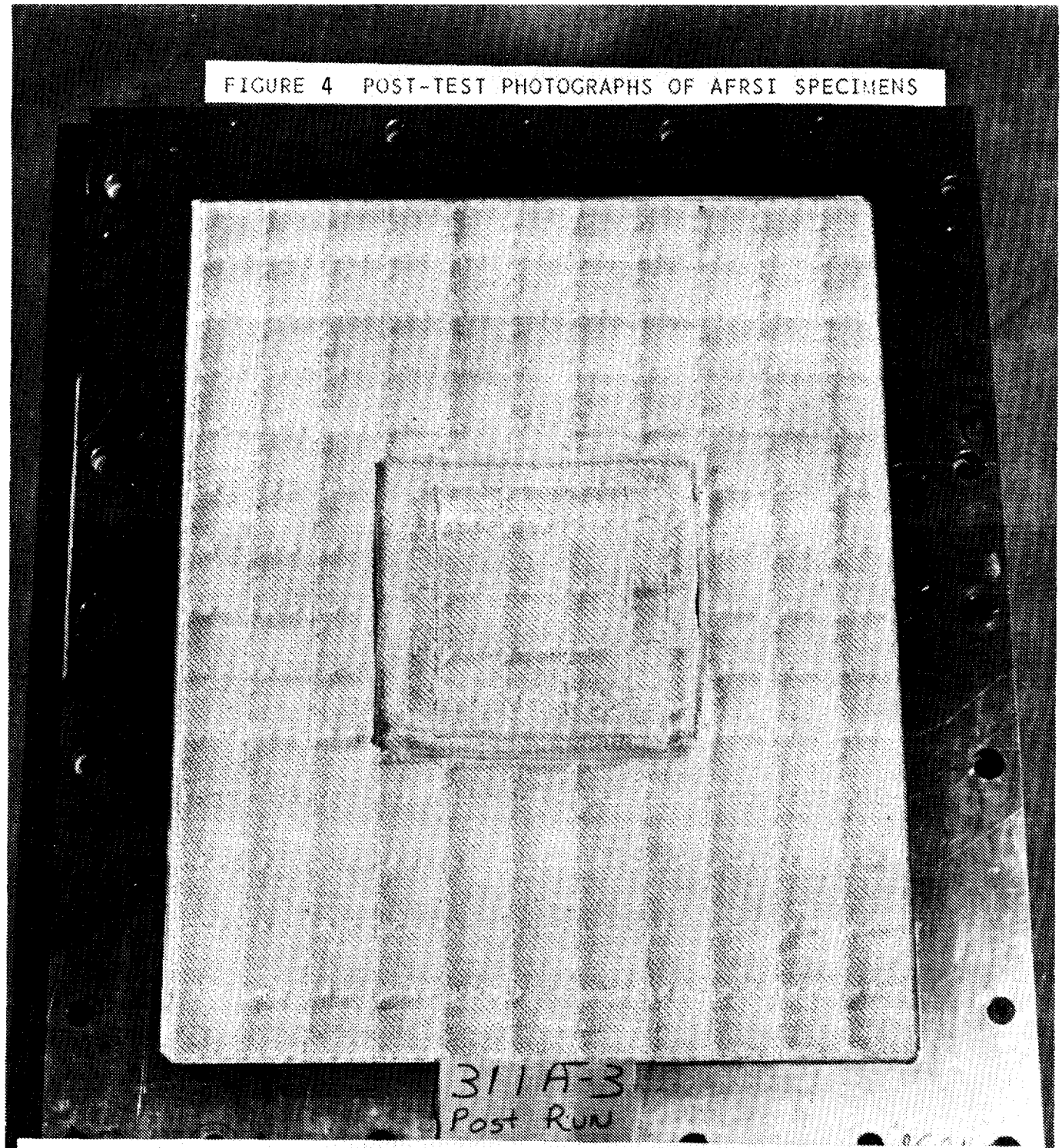
FIGURE 3. TYPICAL PRESSURE COEFFICIENT DATA OS-311 (OS-311-3)

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



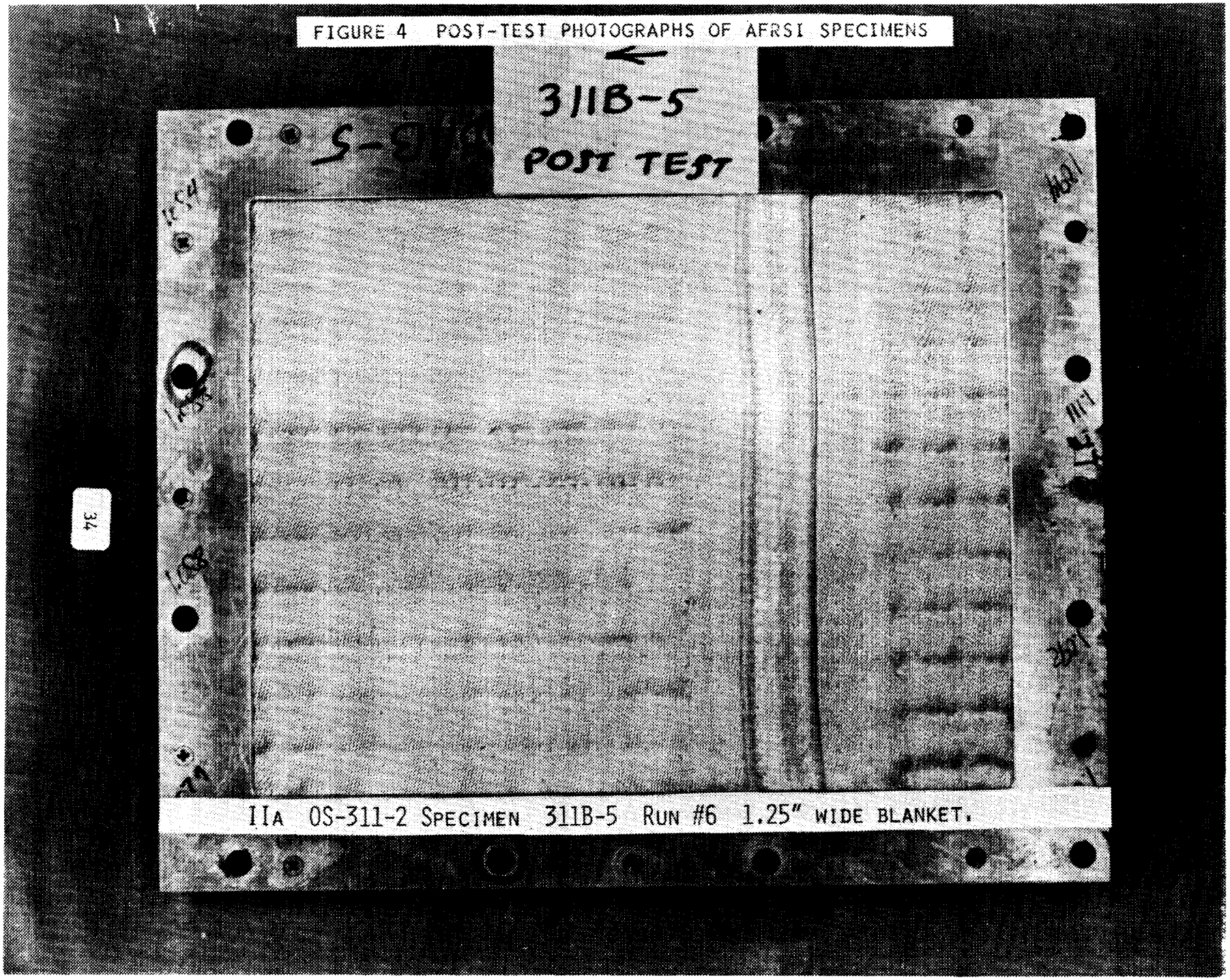
IA OS-311-1 SPECIMEN 311A-2 1.0 PSI PRESSURE BONDED BLANKET.

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

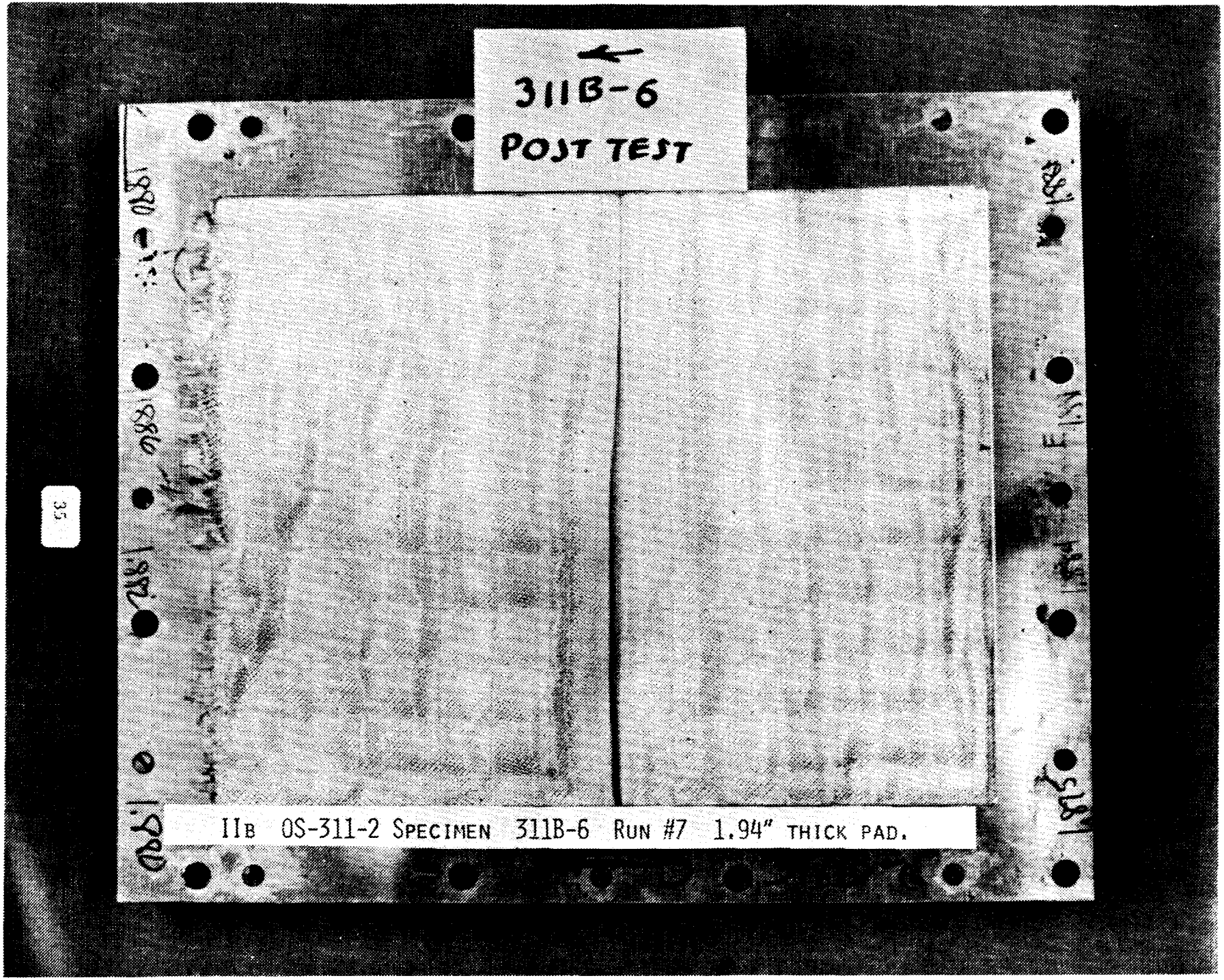


IB OS-311-1 SPECIMEN 311A-3 0.25 PSI PRESSURE BONDED W/REPAIR PLUG.

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

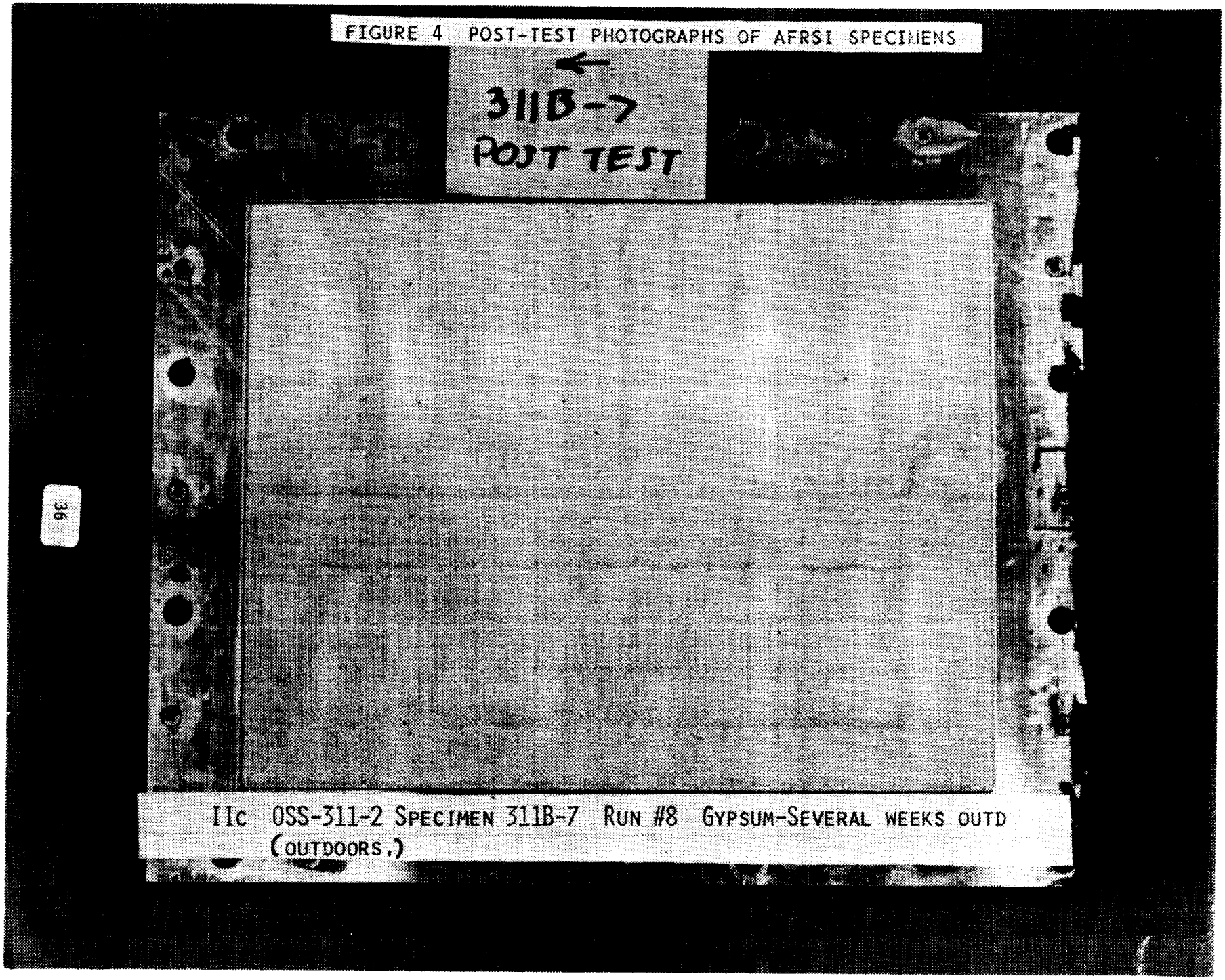


IIA OS-311-2 SPECIMEN 311B-5 RUN #6 1.25" WIDE BLANKET.

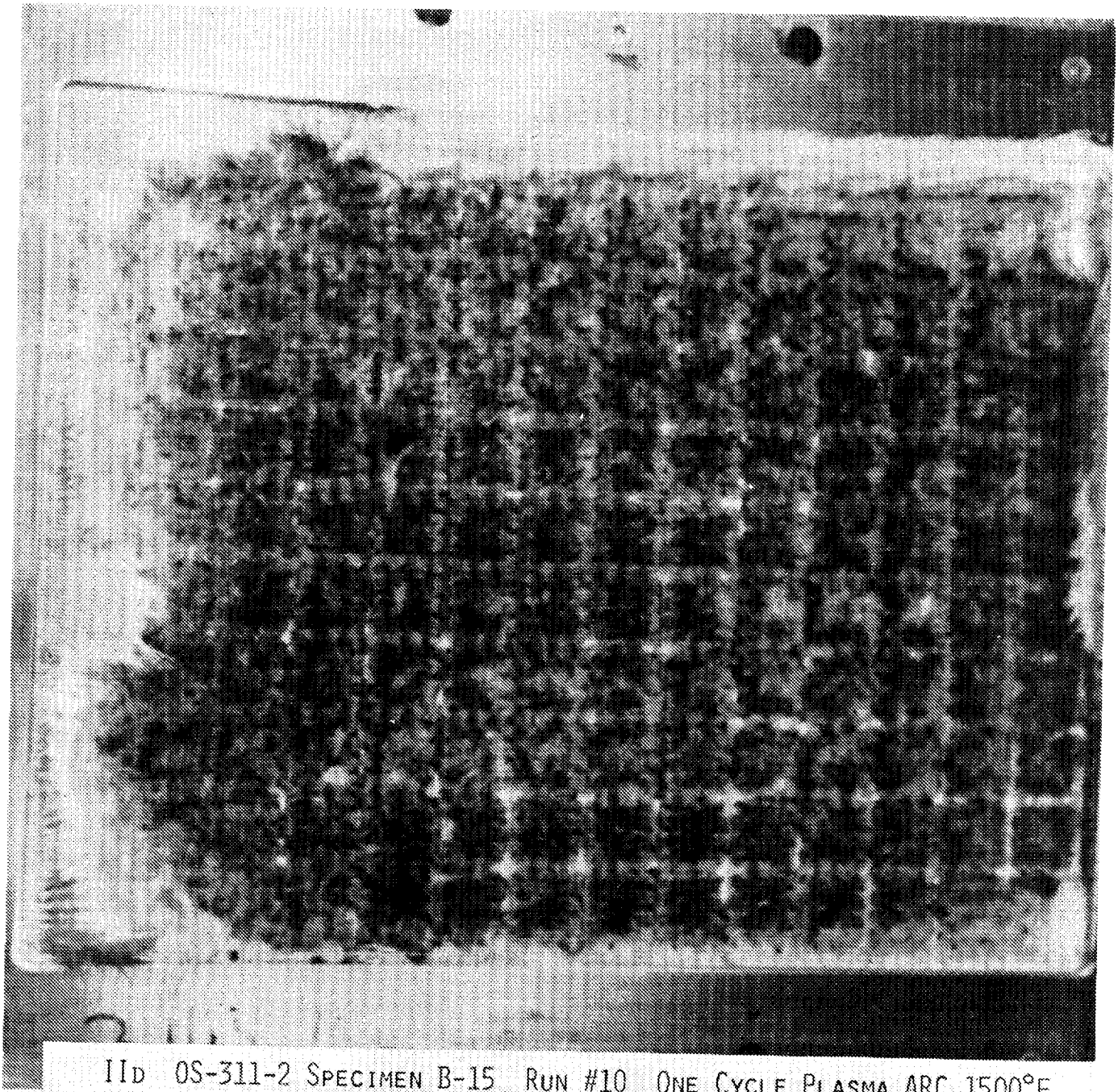


IIB OS-311-2 SPECIMEN 311B-6 RUN #7 1.94" THICK PAD.

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

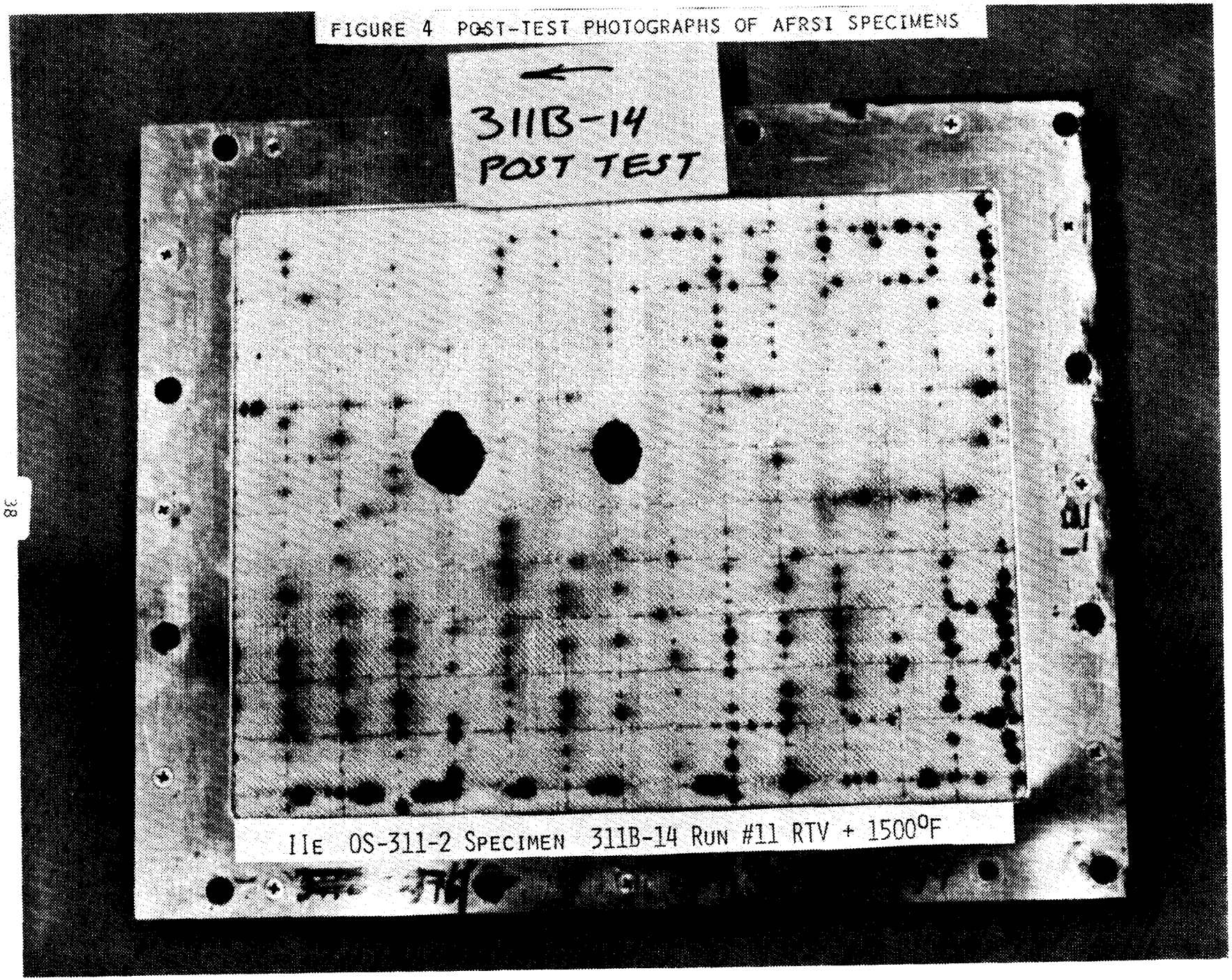


IIc OSS-311-2 SPECIMEN 311B-7 RUN #8 GYPSUM-SEVERAL WEEKS OUTD (OUTDOORS.)



IID OS-311-2 SPECIMEN B-15 RUN #10 ONE CYCLE PLASMA ARC 1500°F

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



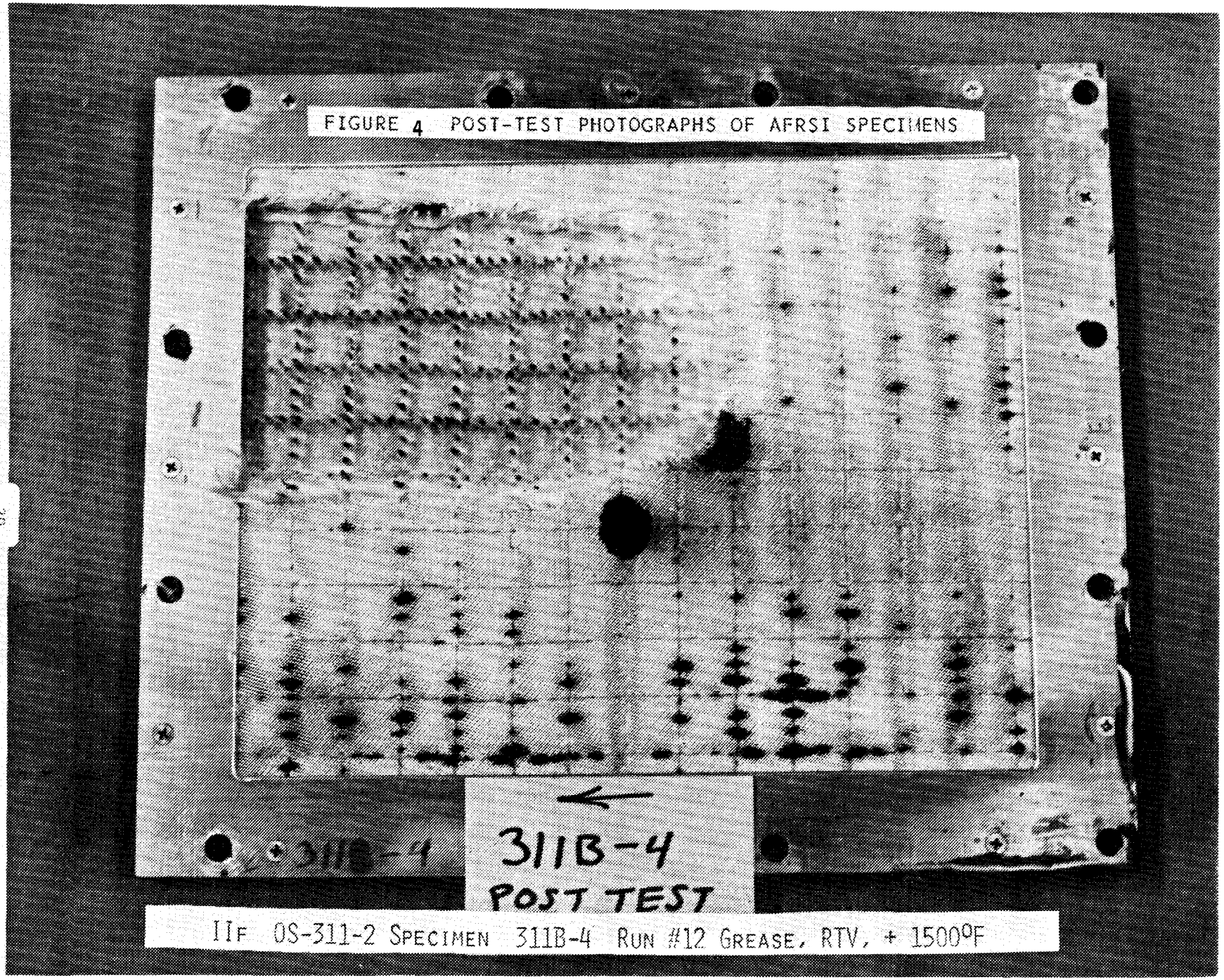
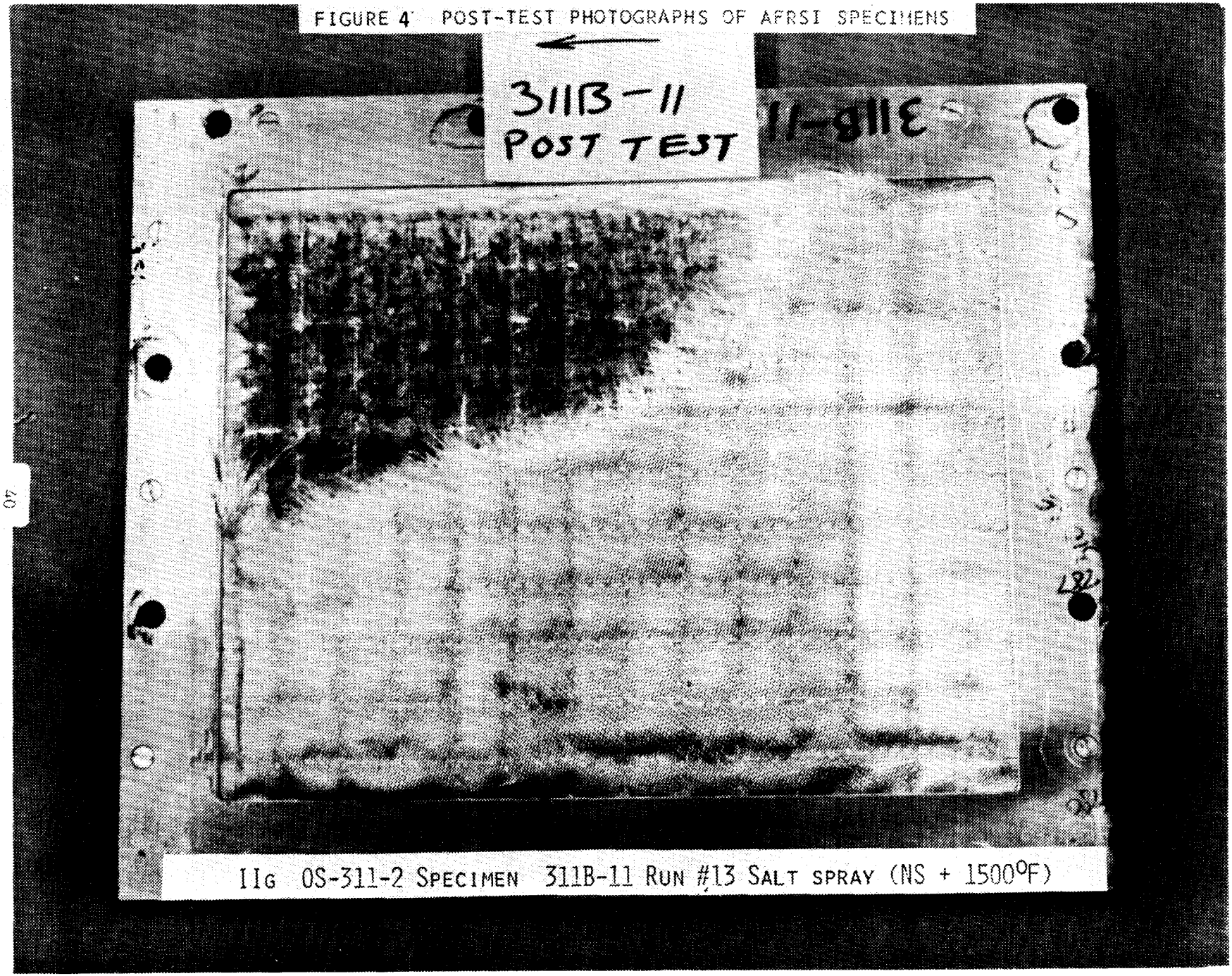


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

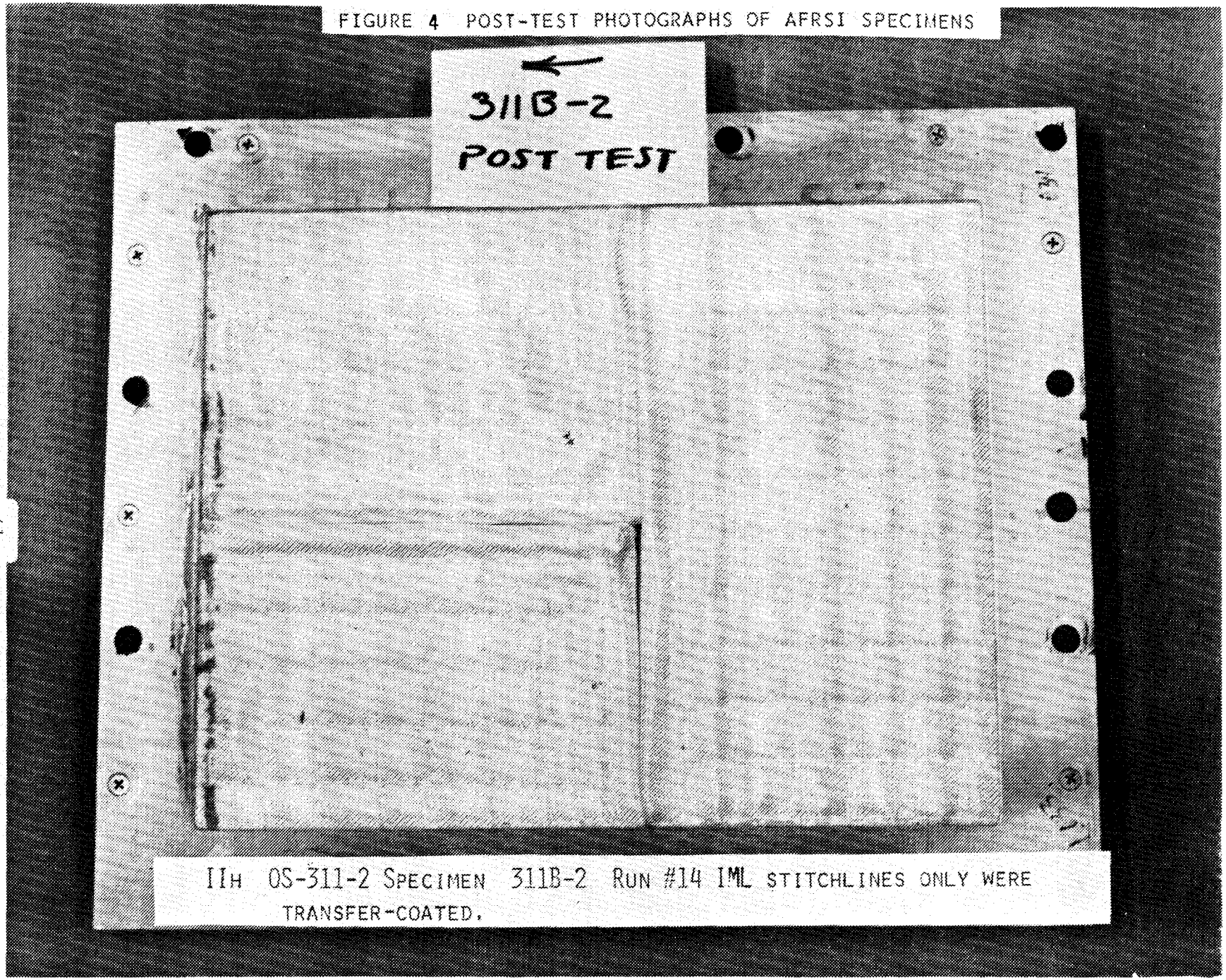
IIF OS-311-2 SPECIMEN 311B-4 RUN #12 GREASE, RTV, + 1500°F

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



IIG OS-311-2 SPECIMEN 311B-11 RUN #13 SALT SPRAY (NS + 1500°F)

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



IIH OS-311-2 SPECIMEN 311B-2 RUN #14 IML STITCHLINES ONLY WERE TRANSFER-COATED.

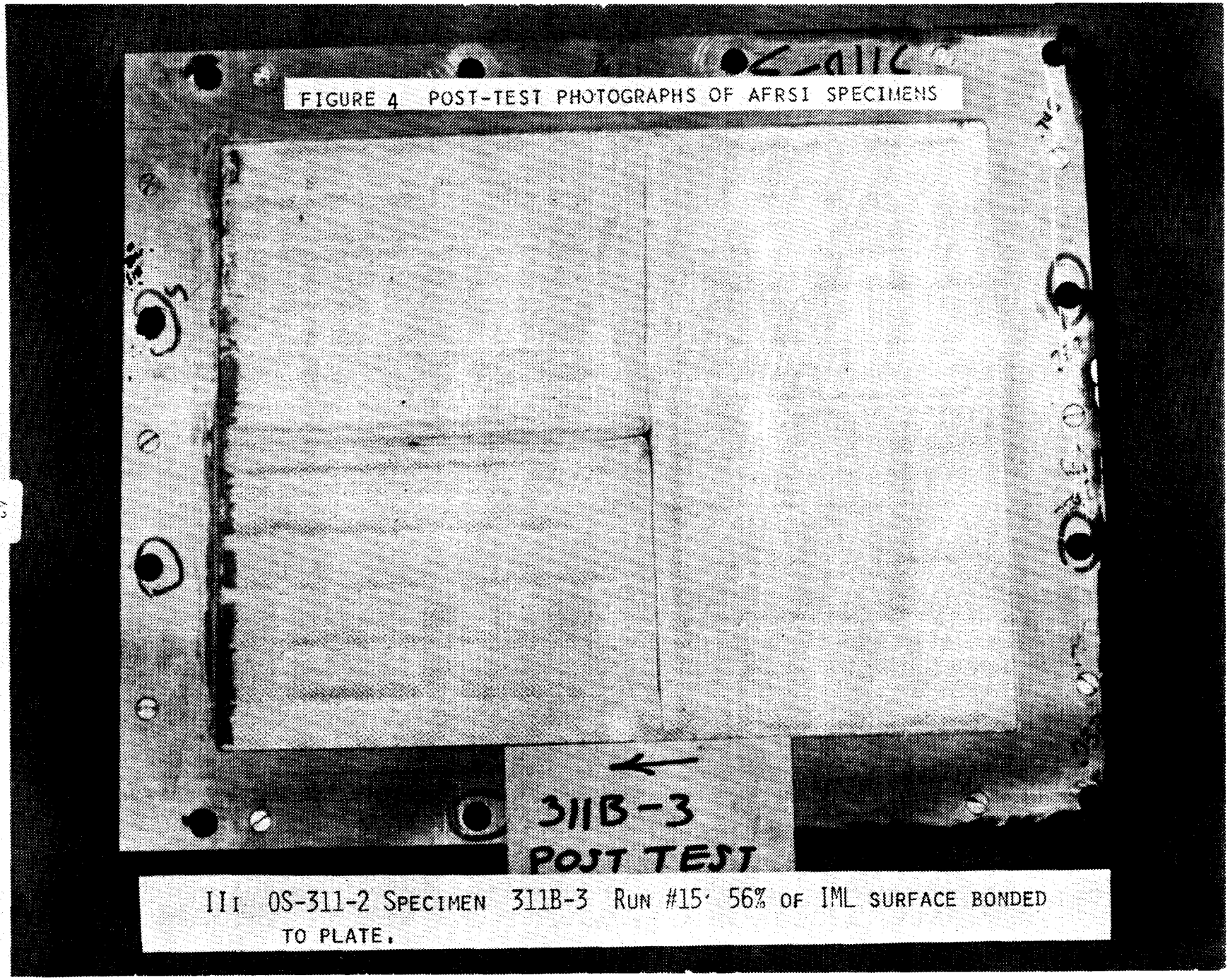


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

III OS-311-2 SPECIMEN 311B-3 RUN #15 56% OF IML SURFACE BONDED TO PLATE.

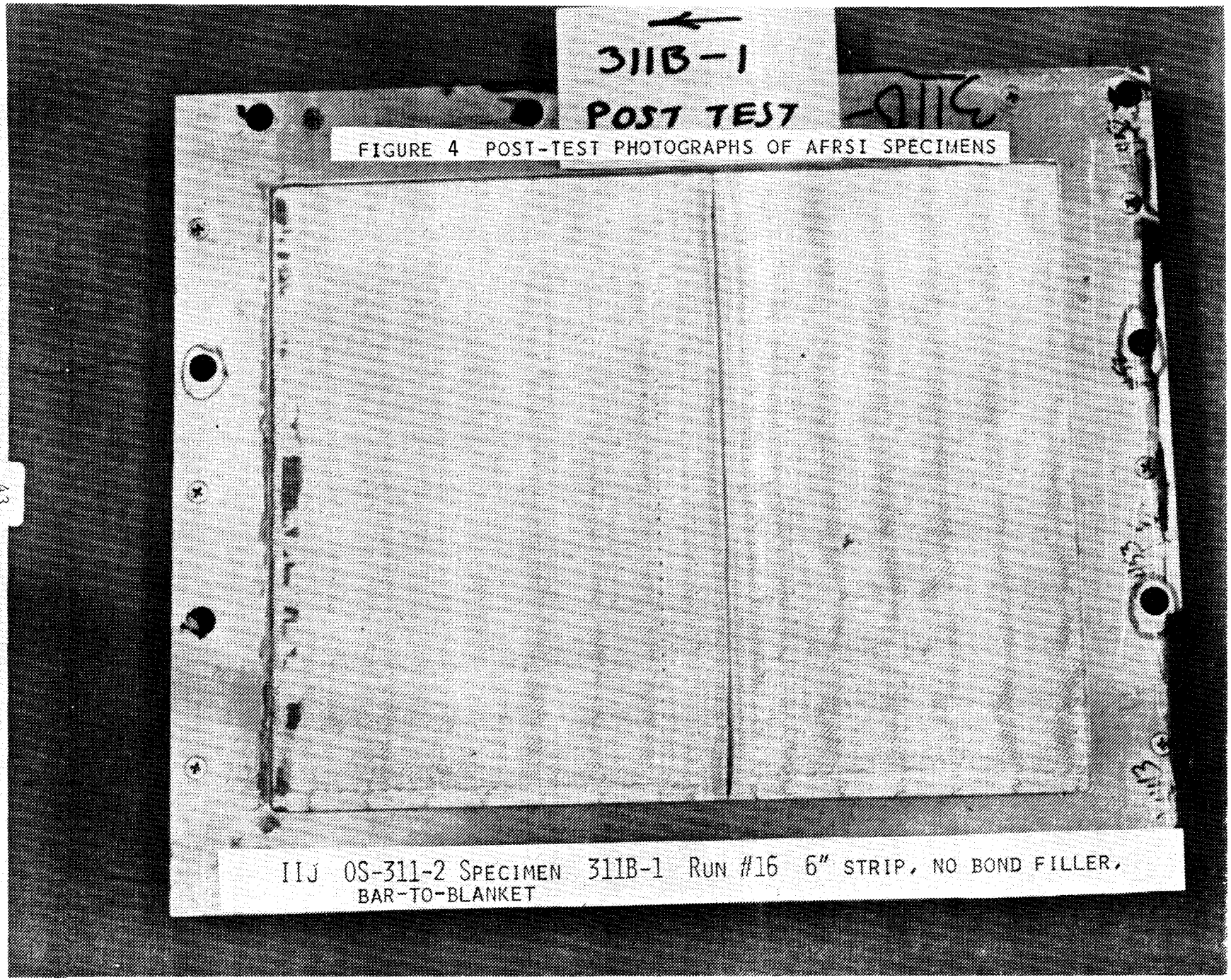


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

IIJ OS-311-2 SPECIMEN 311B-1 RUN #16 6" STRIP, NO BOND FILLER, BAR-TO-BLANKET

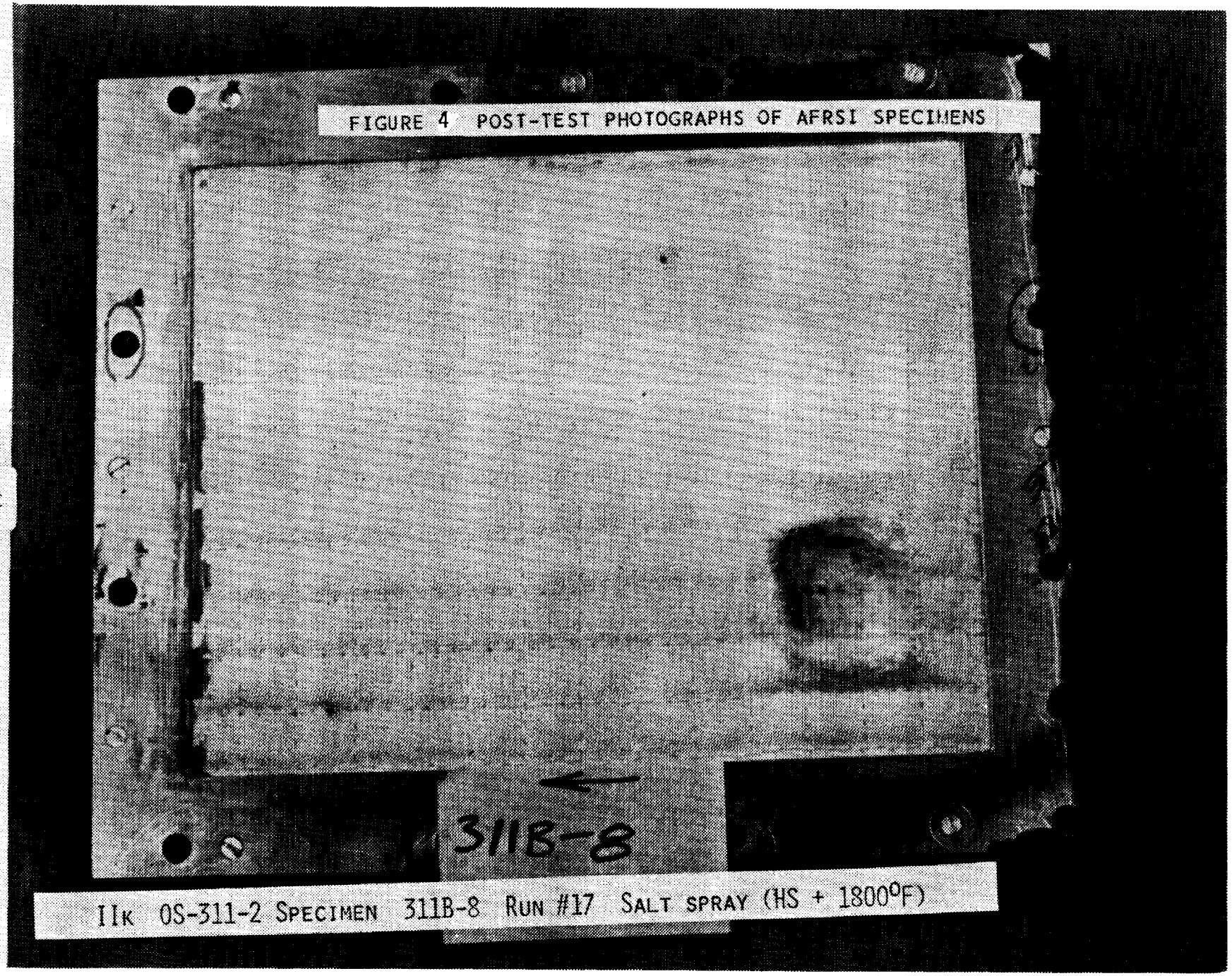
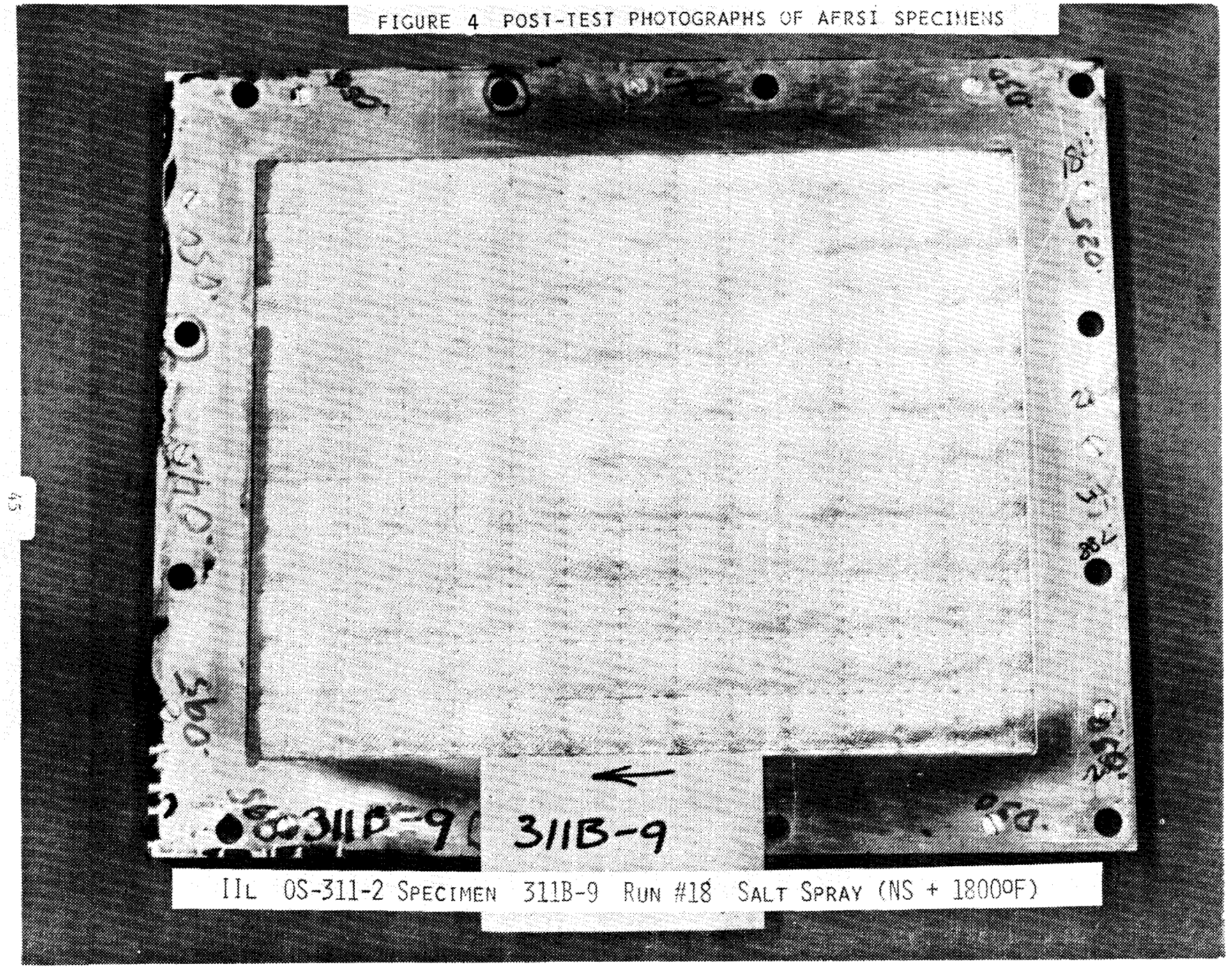


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

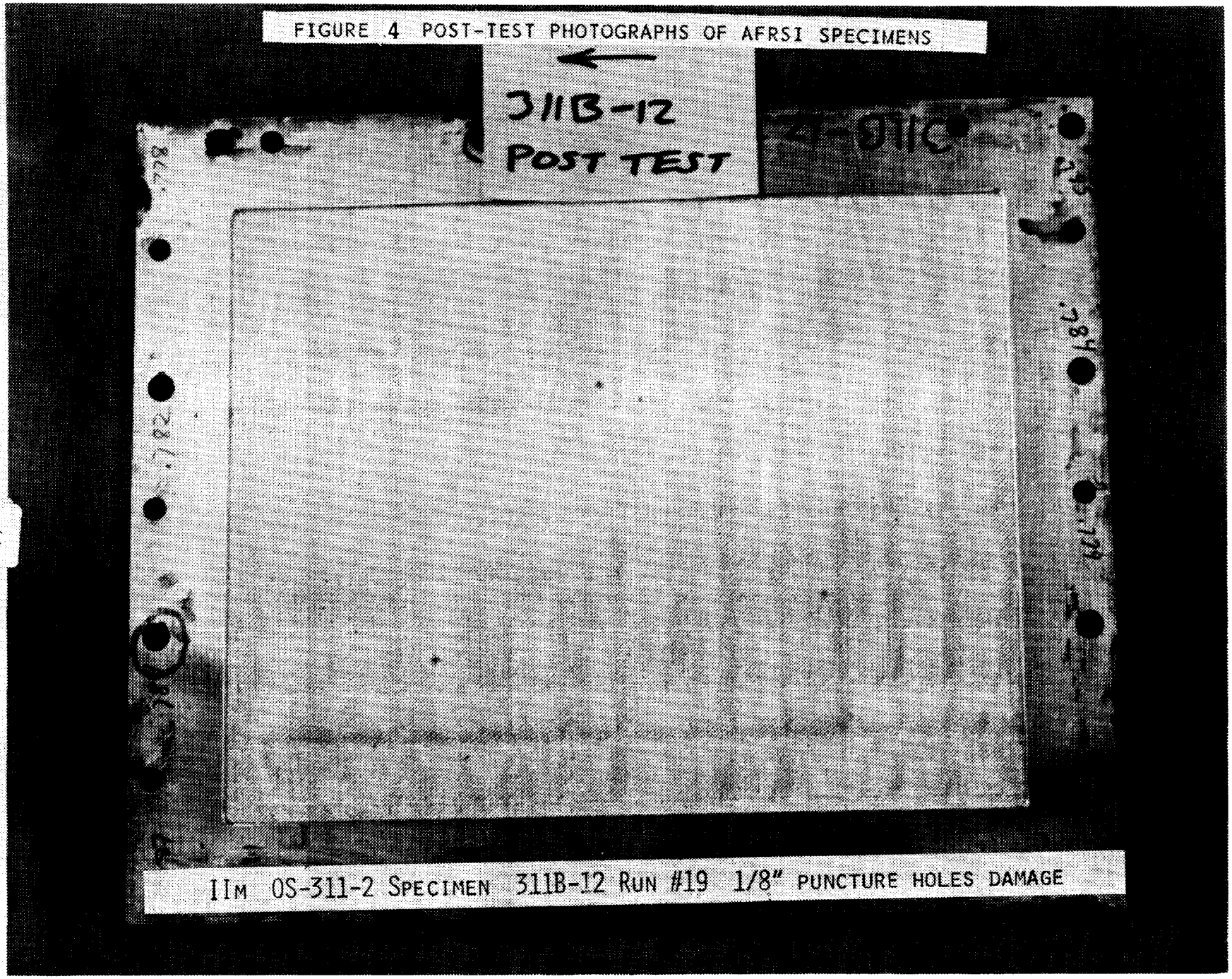
IIK OS-311-2 SPECIMEN 311B-8 RUN #17 SALT SPRAY (HS + 1800°F)

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



IIL OS-311-2 SPECIMEN 311B-9 RUN #18 SALT SPRAY (NS + 1800°F)

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



IIM OS-311-2 SPECIMEN 311B-12 RUN #19 1/8" PUNCTURE HOLES DAMAGE

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

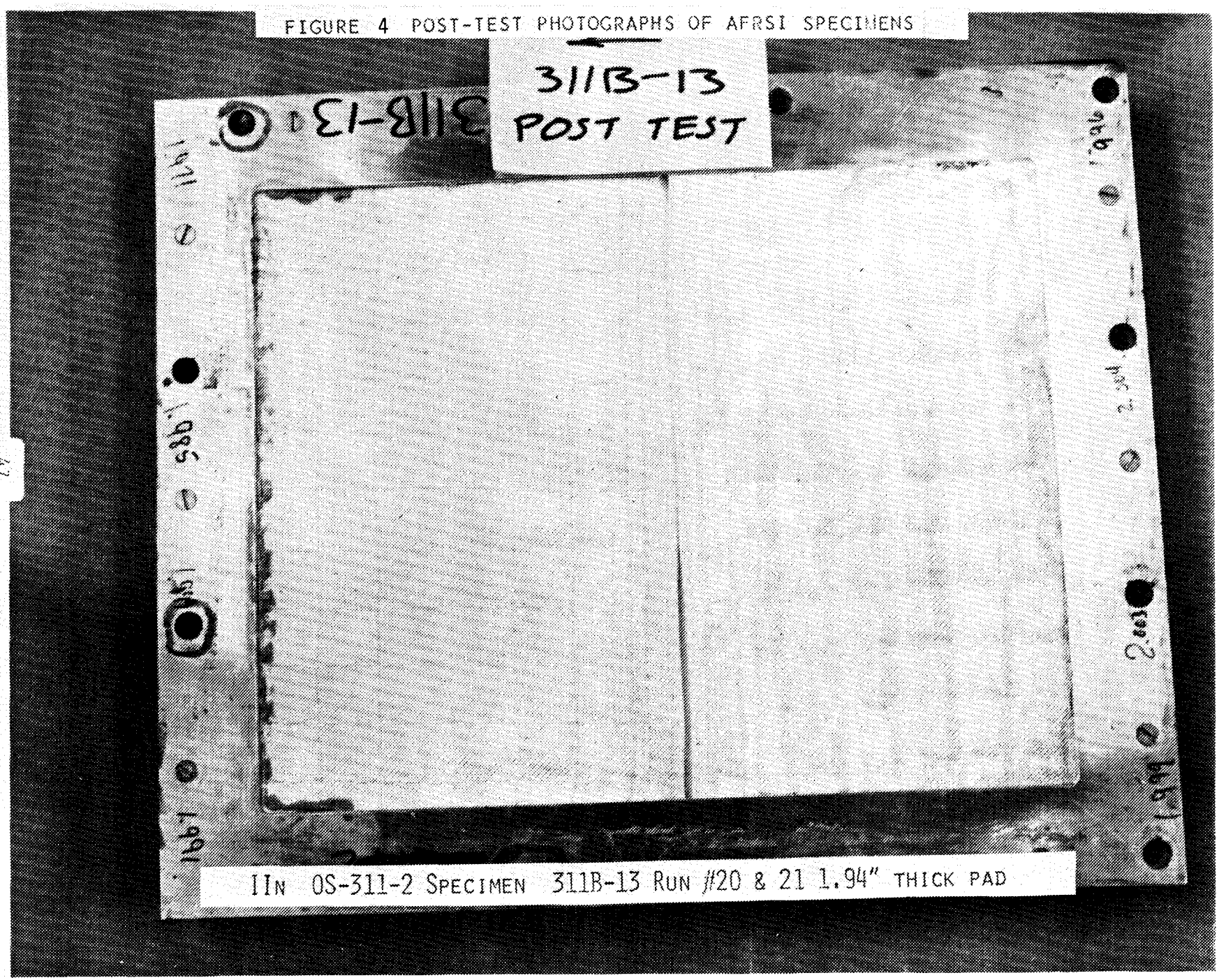
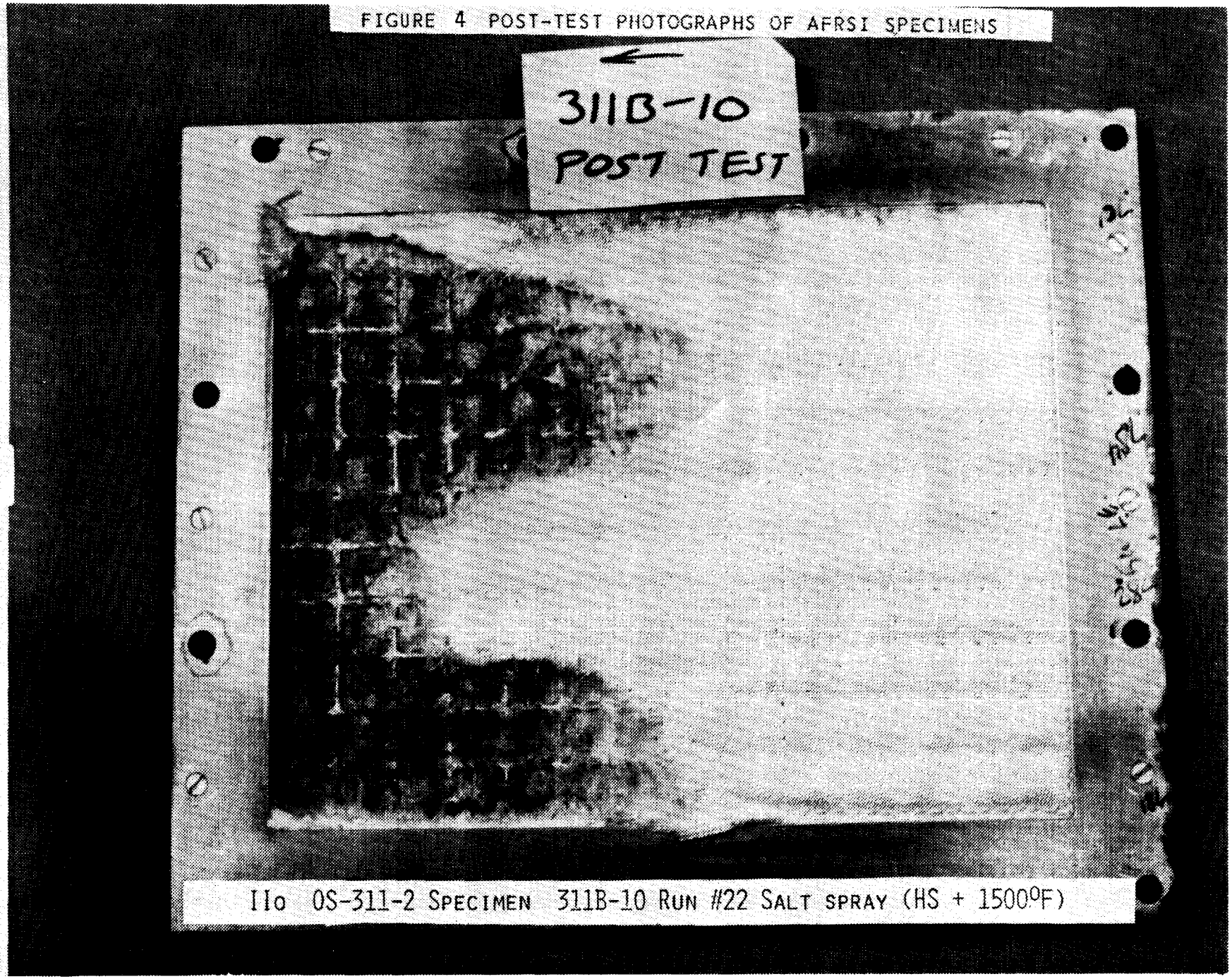
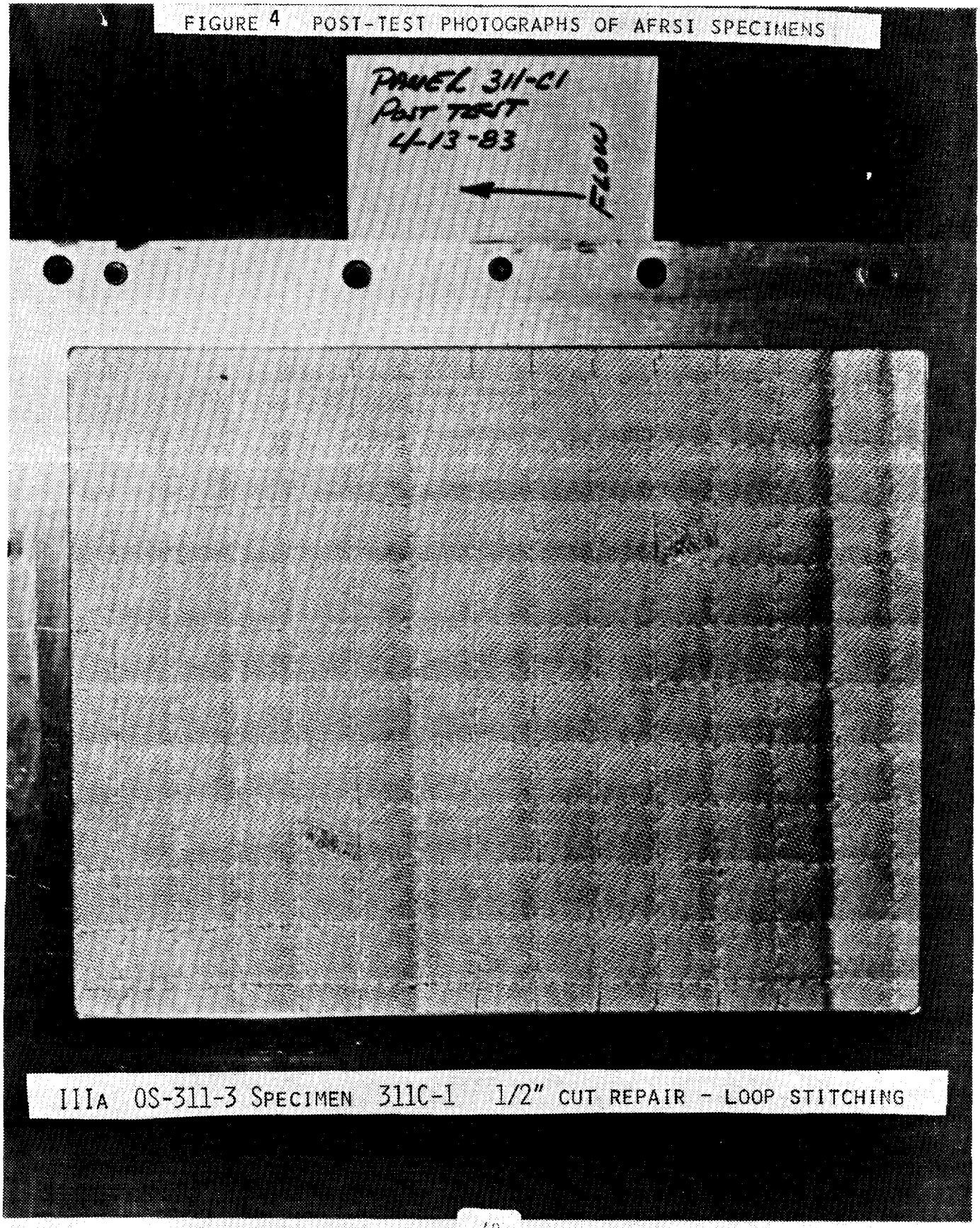


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



IIo OS-311-2 SPECIMEN 311B-10 RUN #22 SALT SPRAY (HS + 1500°F)

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



IIIA OS-311-3 SPECIMEN 311C-1 1/2" CUT REPAIR - LOOP STITCHING

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

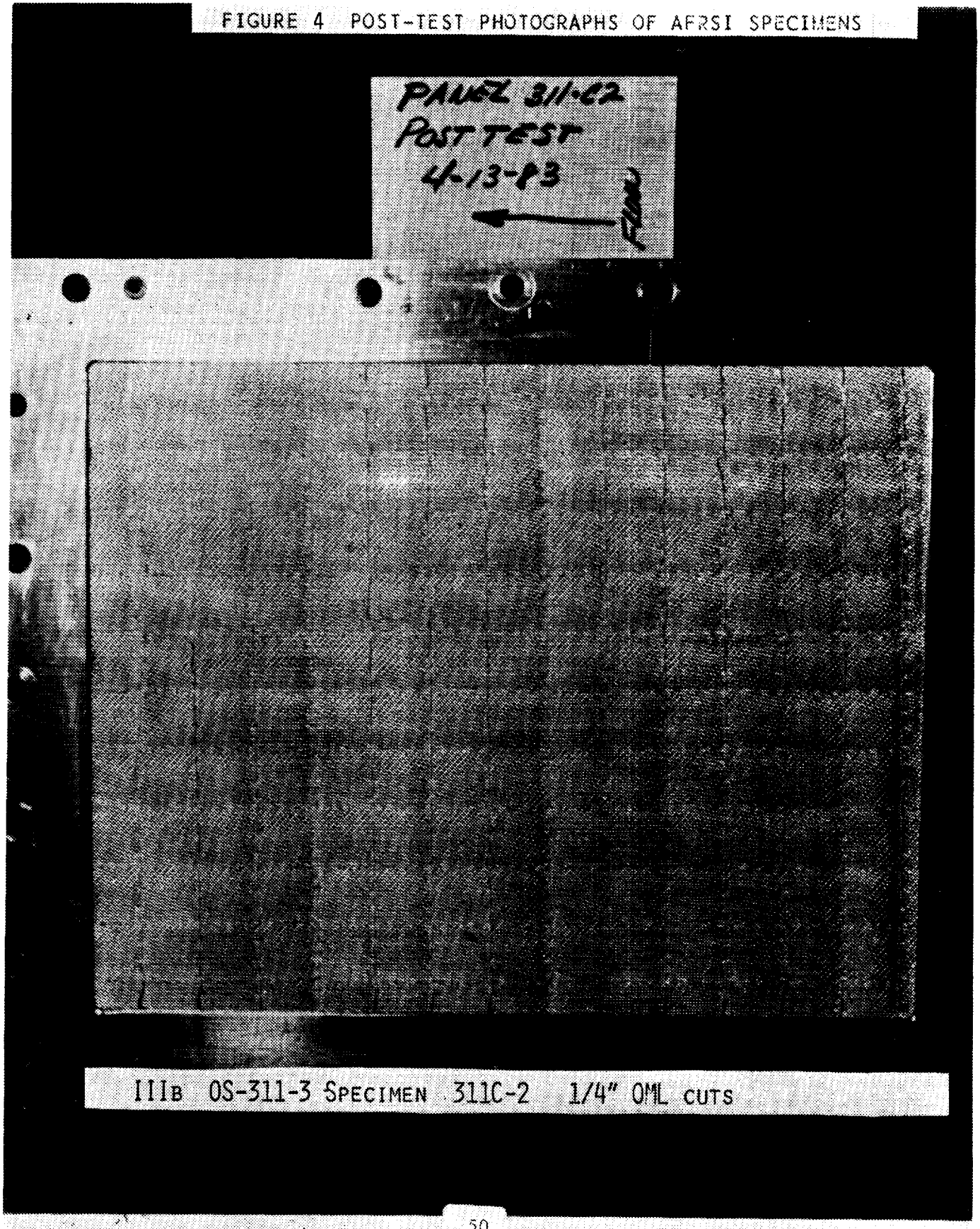
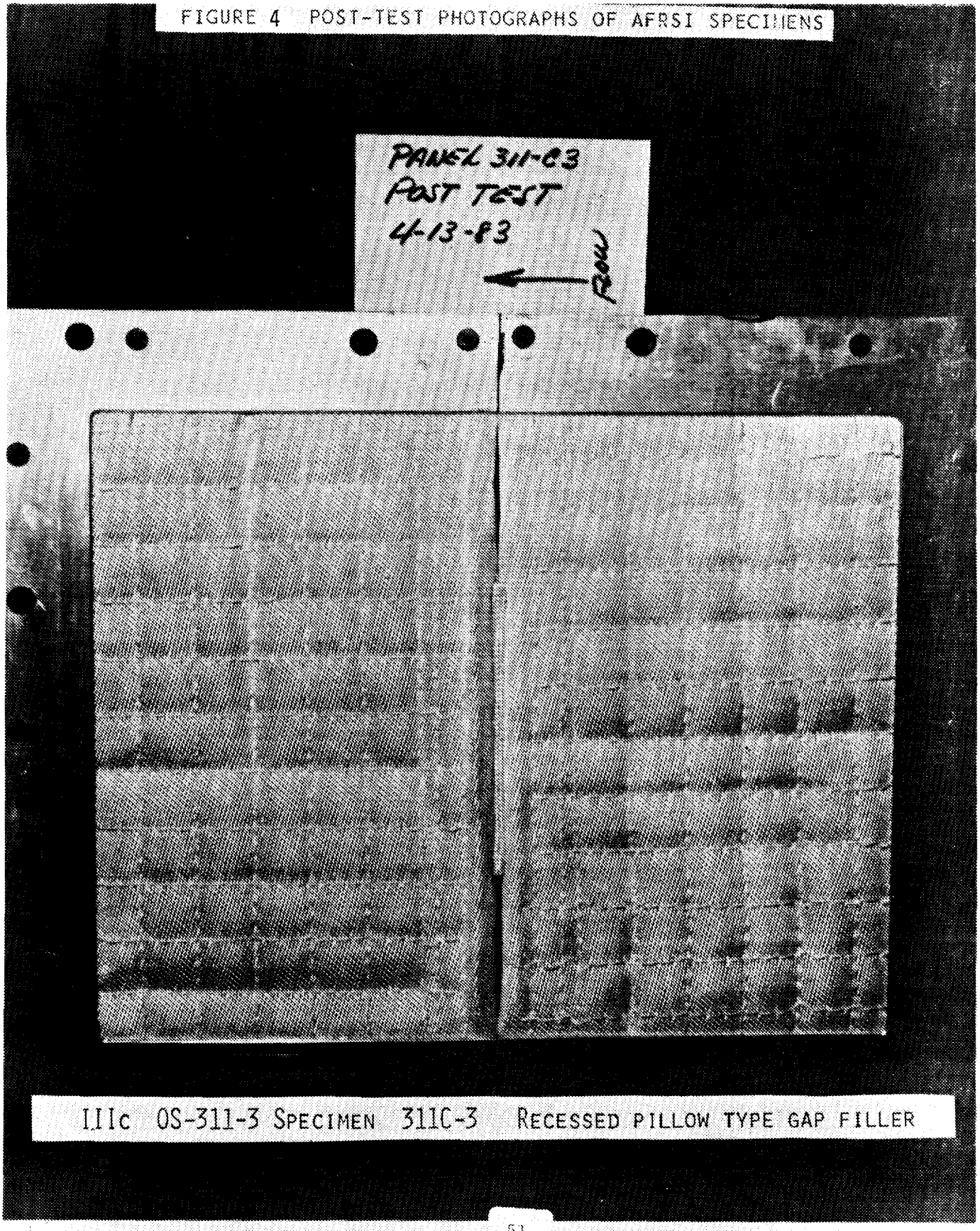
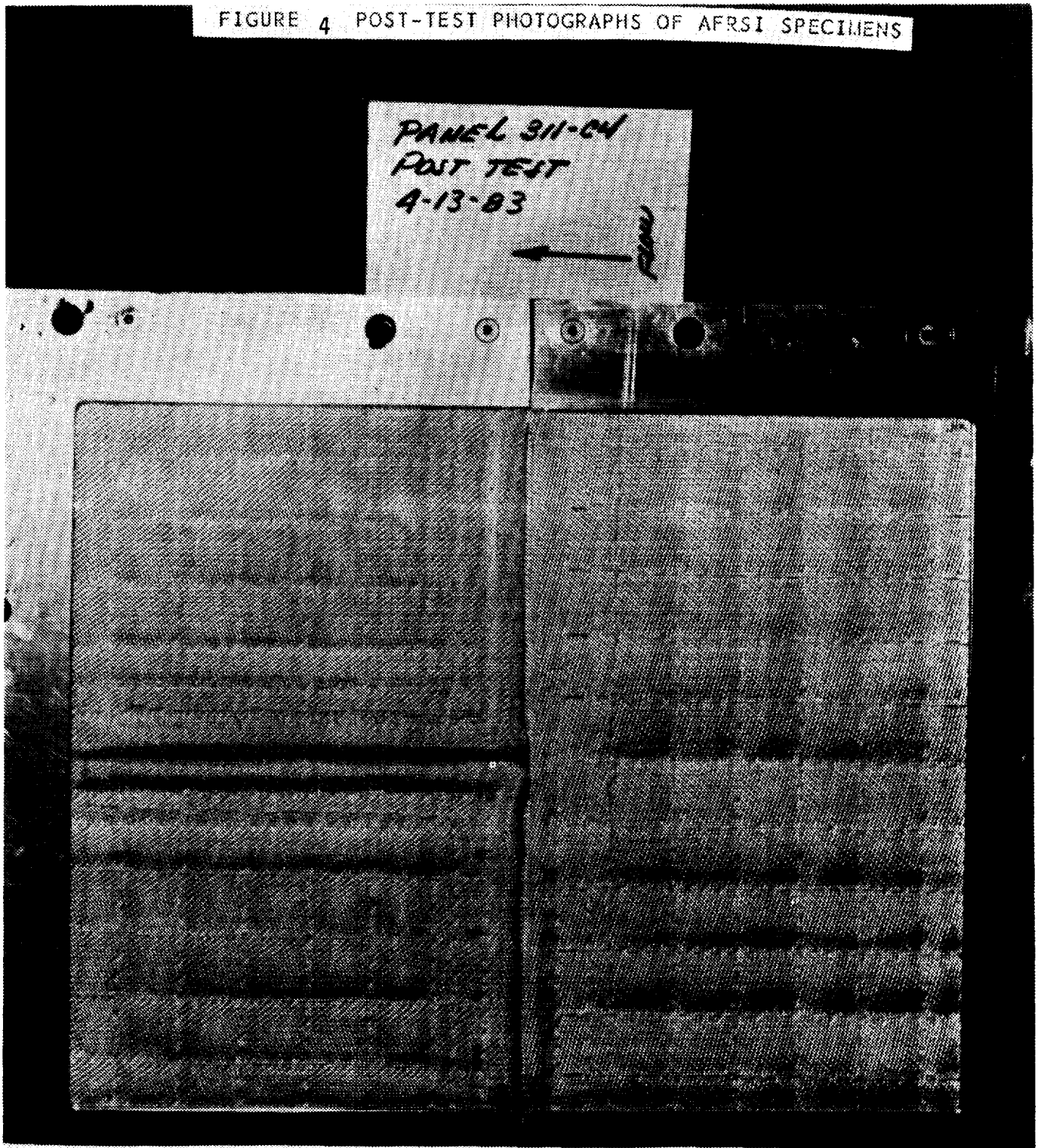


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



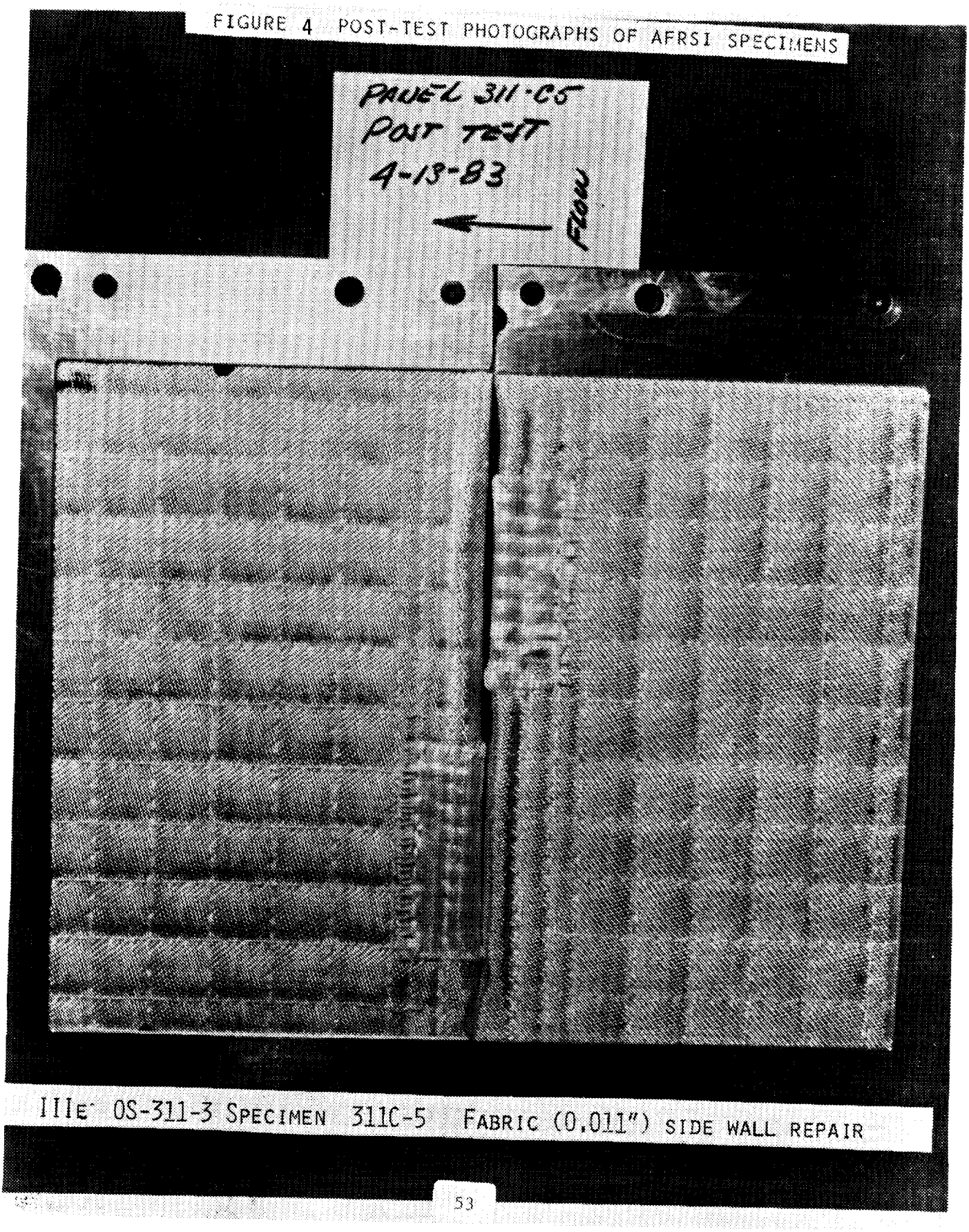
IIIc OS-311-3 SPECIMEN 311C-3 RECESSED PILLOW TYPE GAP FILLER

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



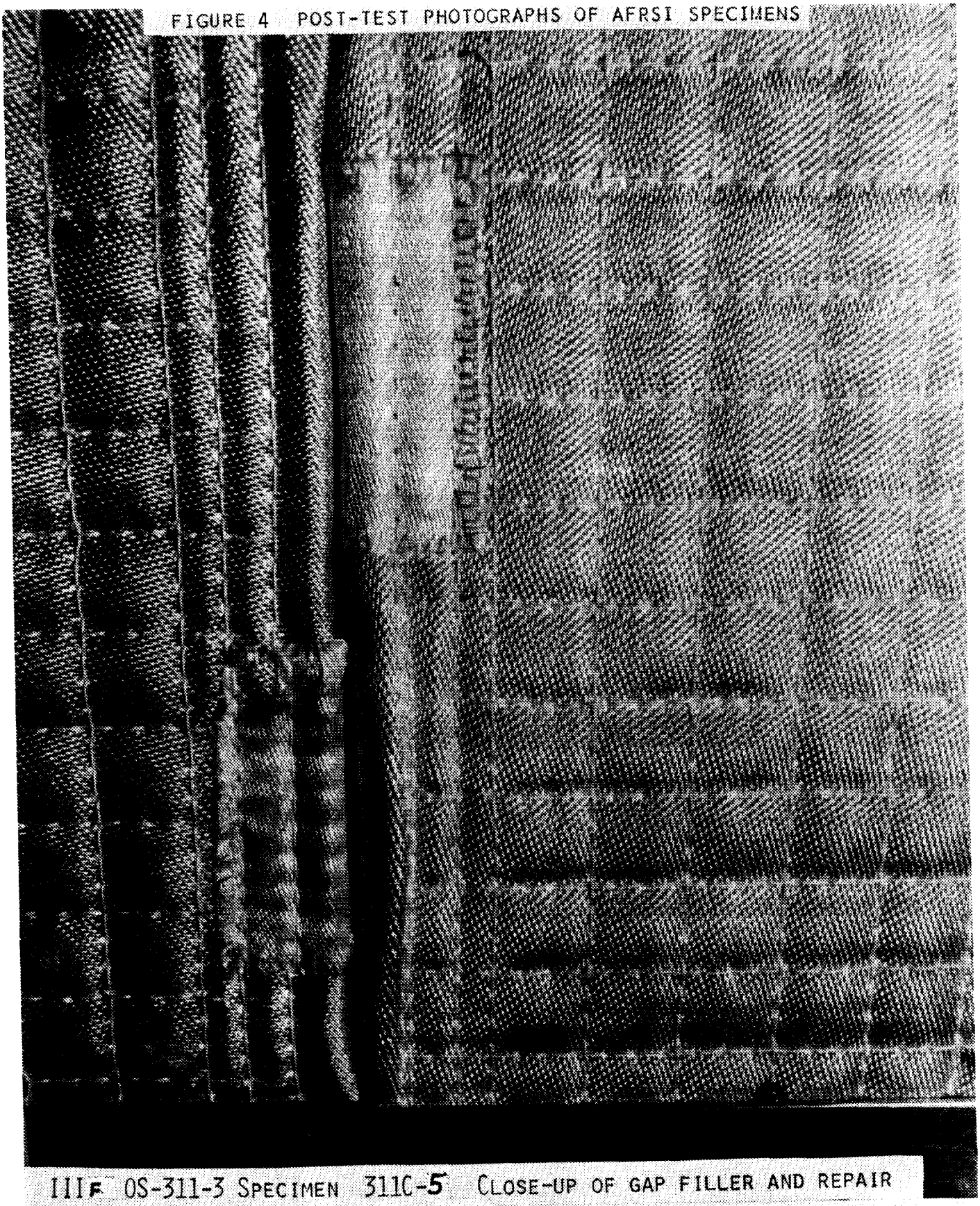
IIID OS-311-3 SPECIMEN 311C-4 RECESSED SOLID CORD (0.90", 0.160") GAP FILLER

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



IIIE OS-311-3 SPECIMEN 311C-5 FABRIC (0.011") SIDE WALL REPAIR

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS



IIIF OS-311-3 SPECIMEN 311C-5 CLOSE-UP OF GAP FILLER AND REPAIR

FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

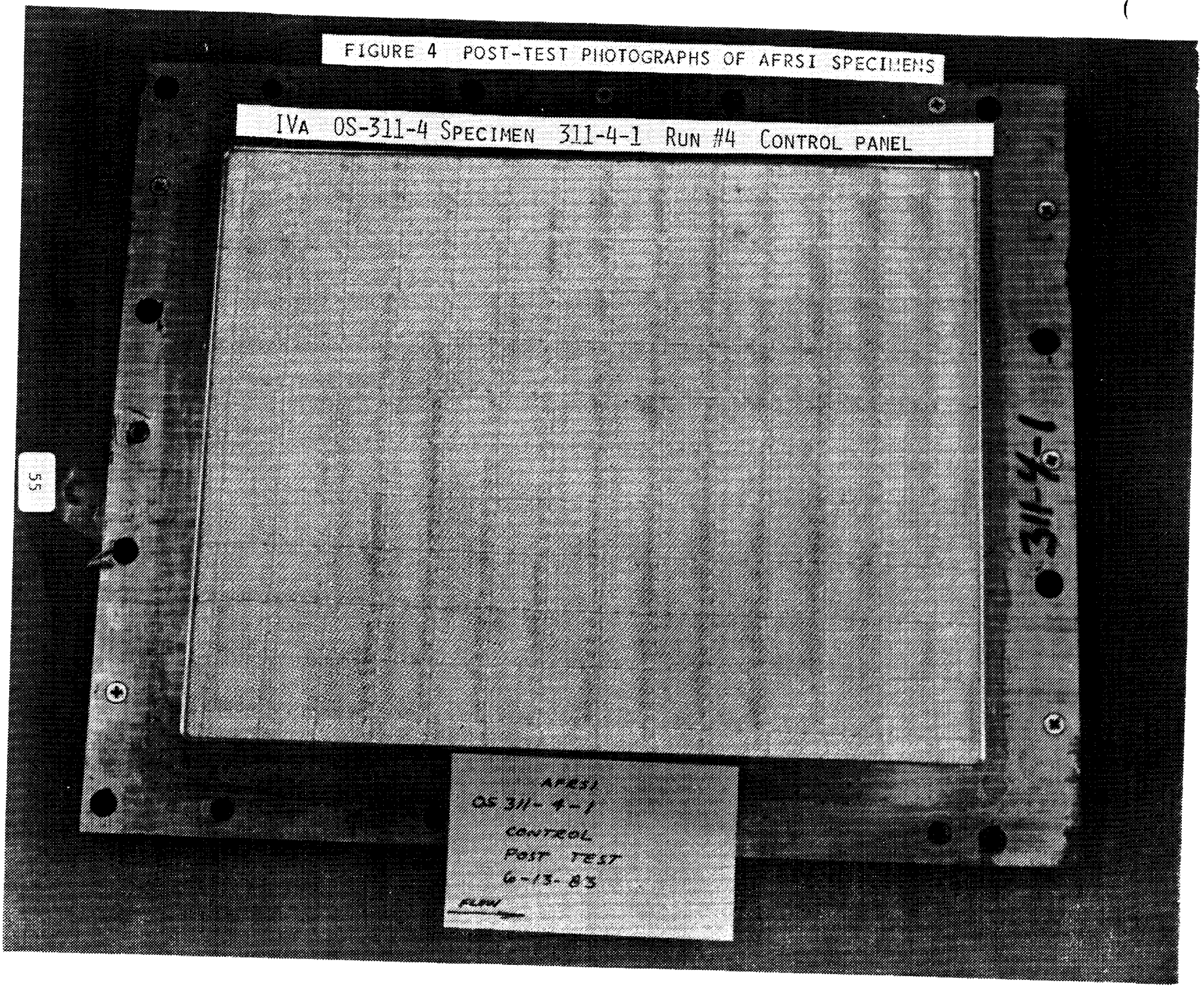


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

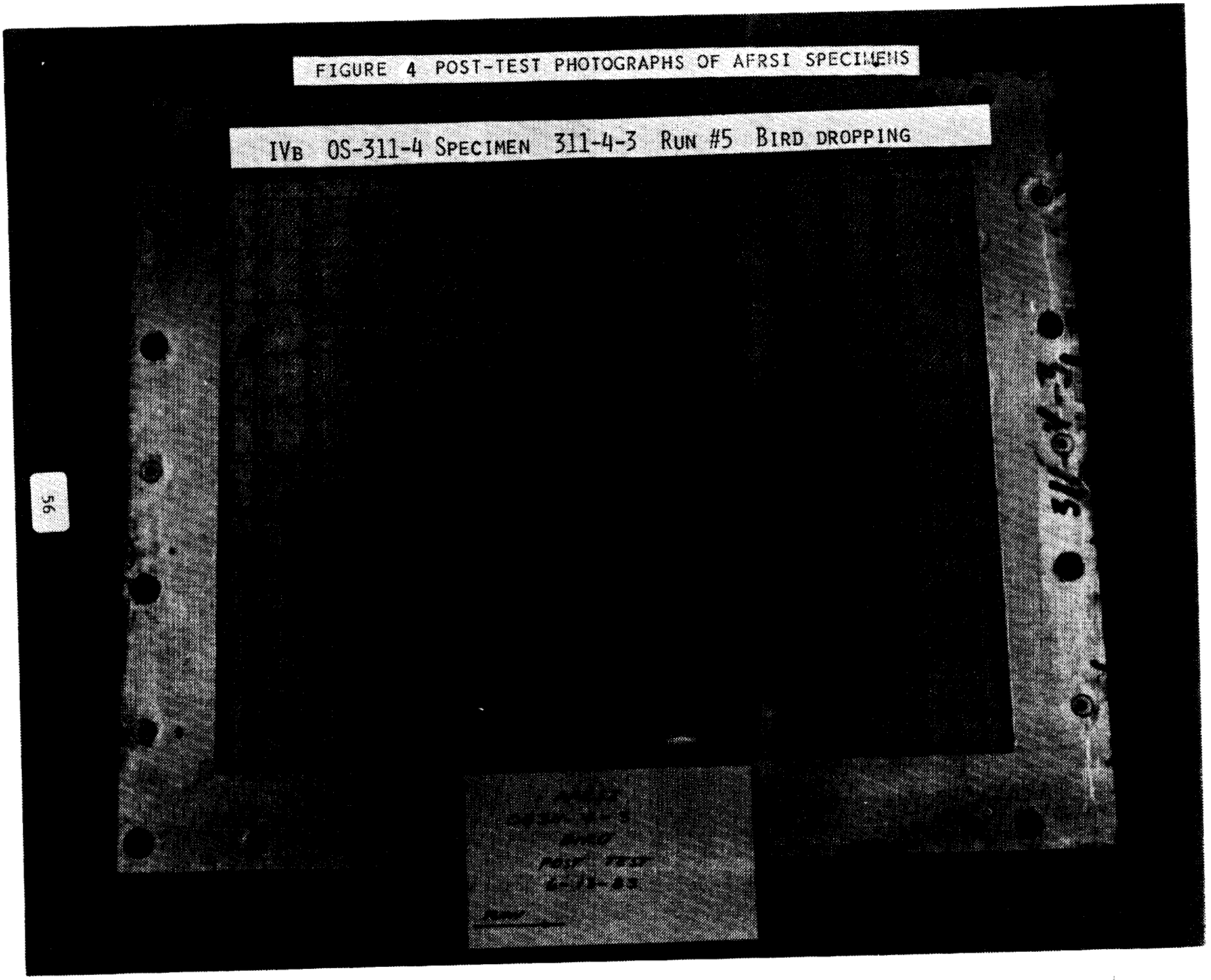


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

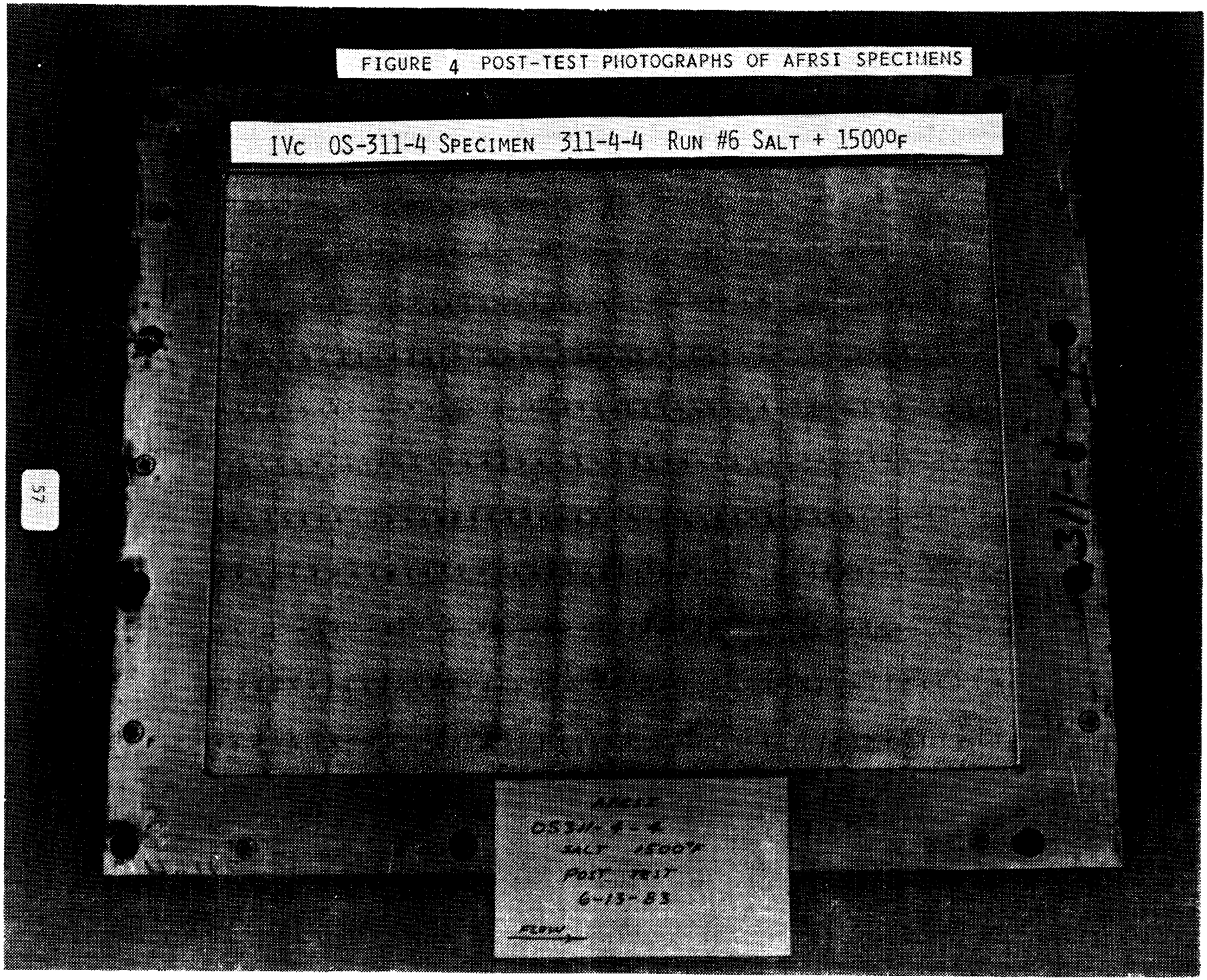


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS

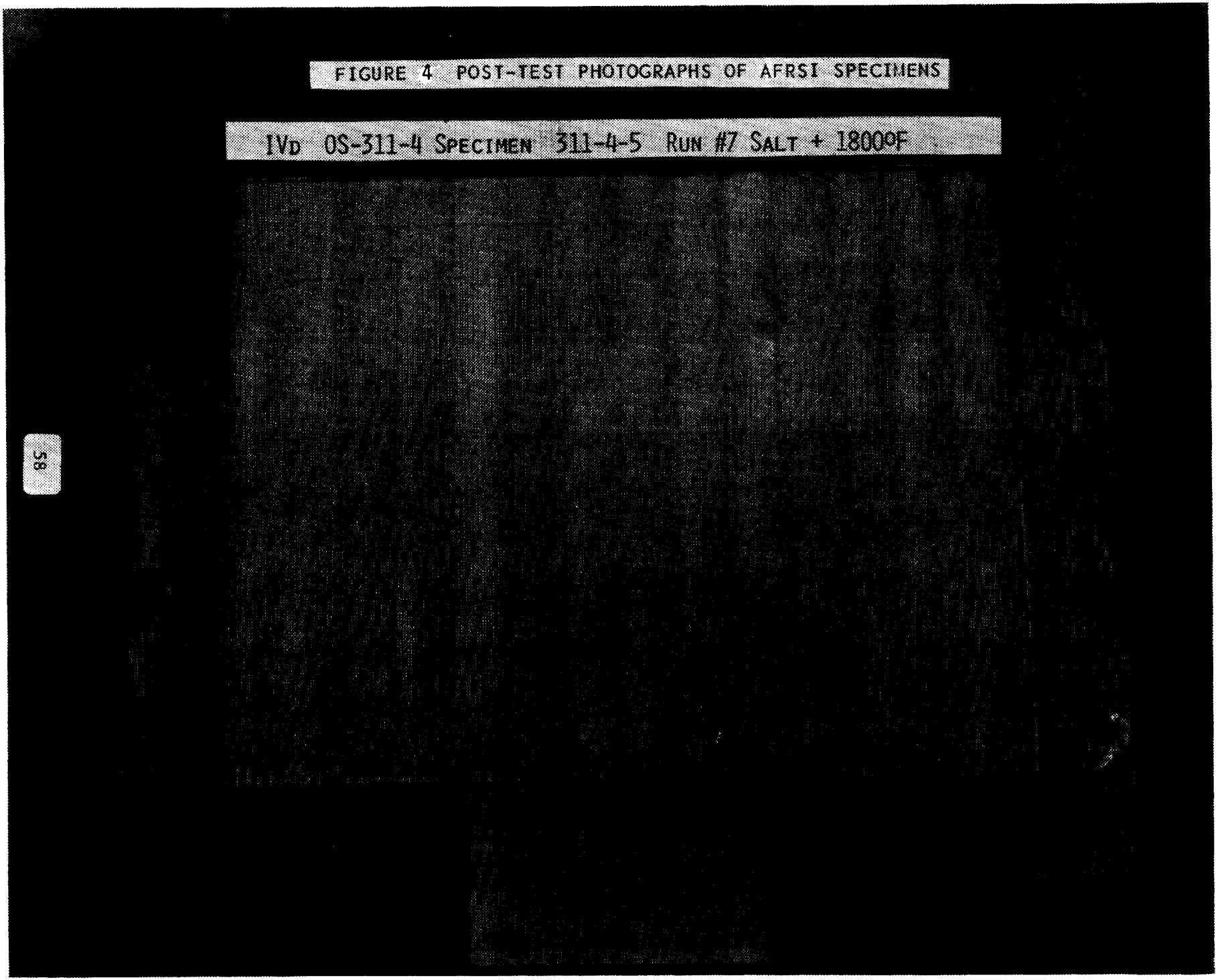


FIGURE 4 POST-TEST PHOTOGRAPHS OF AFRSI SPECIMENS